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ELECTROMECHANICAL components & systems DESIGN

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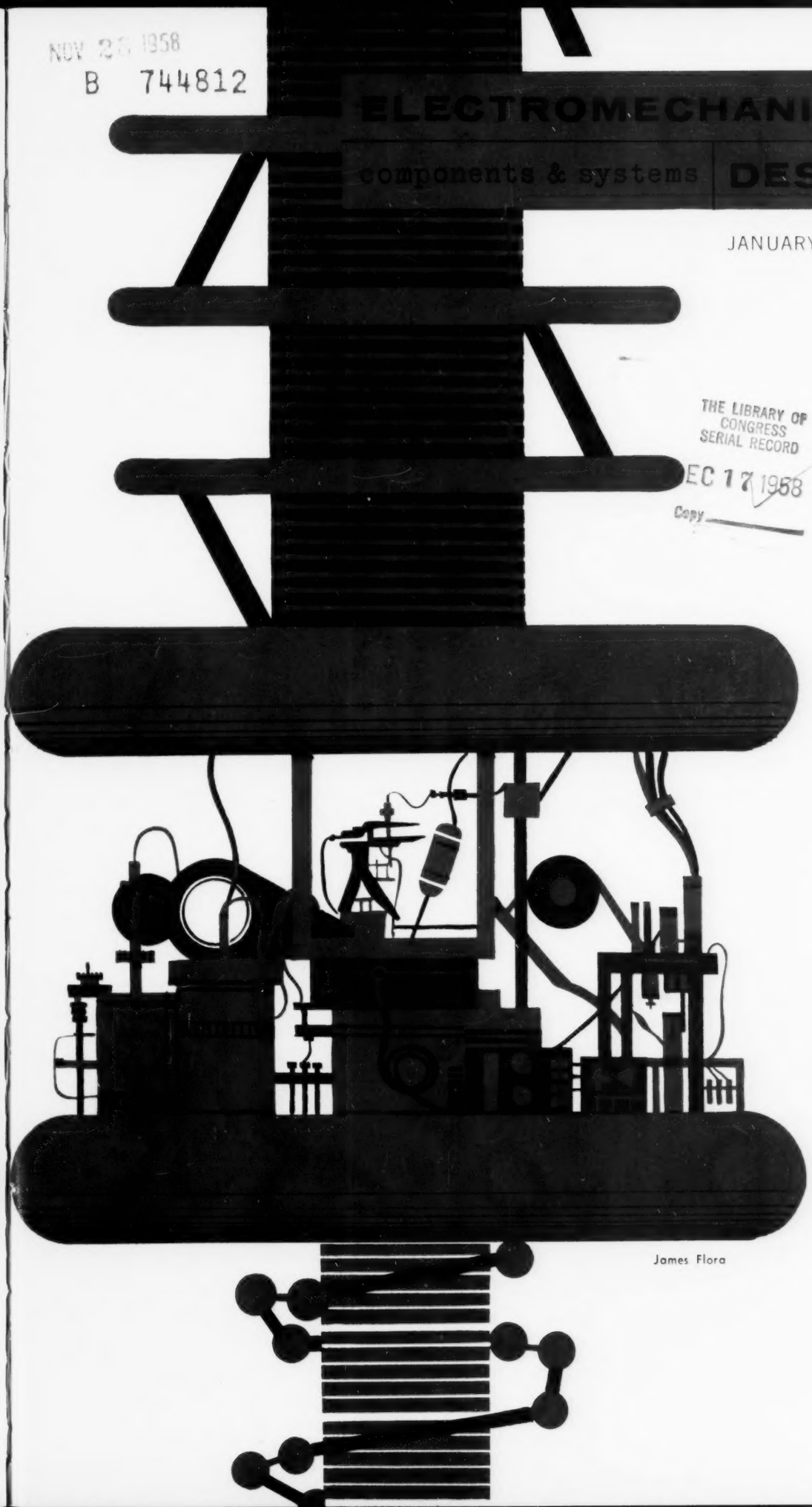


James Flora

analog computor with a NEW TWIST

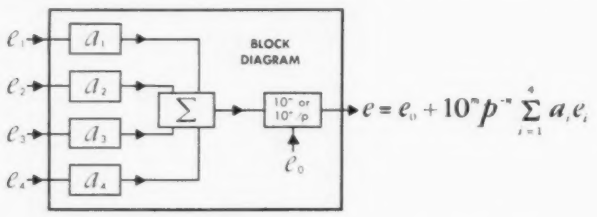
Just twist the knob... decade settings simplify precise parameter programming

In the all-new Philbrick Model K5-U Universal Linear Operator, decade settings replace the usual computing potentiometers to simplify precise parameter programming. Easy to interconnect and use, Model K5-U embodies a variety of operations in one compact, chopper-stabilized unit. This fundamental building block of a general purpose analog computing system permits the analog computor user to extend his design and analysis facilities at reasonable cost.

The Model K5-U accepts up to four voltages and multiplies each by a constant, settable by decade switches to any positive or negative value between 0 and 11.10 in increments of 0.01. These weighted inputs are added together and the sum is then operated on in one of two general ways.

1. The sum may be multiplied by 0, 1, 10, 100 or 1000 and then have added to it a positive or negative index voltage, adjustable from 0 to 50.0 volts in steps of 0.1 volt.

2. The sum may be integrated using any of a wide range of available speeds, viz., 1, 10, 100 or 1000 radians per second. The output voltage may be held at any time, or it may be reset to an initial value which is determined by the index voltage decade setting. The SET-RUN-HOLD modes may be controlled either remotely or manually on the front panel.



Write to George A. Philbrick Researches, Inc., 230 Congress St., Boston 10, Mass., for the name of the PHILBRICK representative in your area and Technical Bulletin EM-1

GEORGE A.
PHILBRICK
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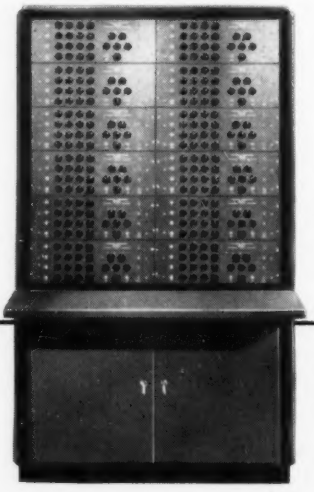
230 Congress Street, Boston 10, Massachusetts

- ***Easy to read three-digit decade settings*** — precise adjustment of parameters now possible even during computation.
- ***"Pot-setting" is outmoded*** — time-consuming calibration voltage measurements are eliminated.
- ***Extravagant servo-setting is surpassed*** — simply "read it on the dials" to three figures.
- ***Additional inverting amplifiers are unnecessary*** — individual inputs may be added, subtracted, or removed by the flick of a switch.
- ***Choose your time scale*** — continuous real-time computing, high-speed repetitive operation, and "single-shot" solutions are *all* inherent.
- ***Versatile linear building block*** — Summing Amplifier, Integrating Amplifier, Inverting Amplifier, Initial Conditions, Set-Run-Hold Relays are all available at your fingertips.
- ***Mounting*** — occupies 7" vertically in standard relay rack or enclosure.



Model K5-U retains the convenience, economy and versatility of modular assembly.

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ELECTROMECHANICAL

components & systems **DESIGN**

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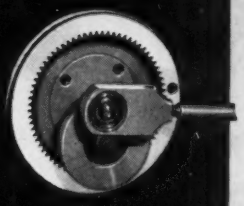

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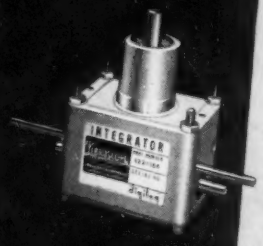

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Offices

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IN OUR NEXT ISSUE

Starting with our next issue, March, 1958, ELECTROMECHANICAL components & systems DESIGN becomes a monthly. Here's a preview of some of the highlights of that issue:

- Emile Labin reports from France on a variable speed torque transmitter design based on an eddy current slip coupling.
- R. C. Vickery discusses free radicals, what they are, their use as new tools in R/D and concludes with a new approach for their concentration and stabilization.
- H. F. Spirer gives you six precise steps on how to freeze operational specifications to achieve *unreliable* designs.
- What is your company in business for? The manner in which you answer this question aids you in LRP—Long Range Planning. Jesse E. Hobson tells what it is and how it is applied.
- Andrew R. MacAndrew clears up some misconceptions about the comparision between Soviet and American engineering education problems and nails down a primary reason for the successes of Soviet research with important implications for U. S. R/D.
- James Brian Quinn, assistant Dean of the Amos Tuck School of Business Administration at Dartmouth College, spells out a comprehensive approach to industrial research evaluation.
- To overcome heat problems in electronic and electromechanical equipment, more and more engineers are using finned designs. H. D. Conway shows you how to design these fins to avoid thermal failures.
- C. M. Ryerson of RCA shows you how to calculate the reliability of equipment using Poisson's distribution.

And in Components & Systems design:

- Just about the last word in how to use platinum resistance thermometers in temperature measurement and control.
- "How to" design transistorized power supplies that function accurately under severe ambient conditions.
- Precision voltage monitor for telemetric systems.
- New ductile bismuth for application in thermocouples, grids, gauss meters, voltage regulators and resistance controlled circuits.
- Digital clock design for data loggers, printers, computers and telemetering systems.
- Computer memory with an air cushion design.
- Superpressure made easy with a new chamber design.
- Microsecond photography for stopping high transient events.
- Small optical tracker developed at M.I.T.
- Translations of selected Russian Reports.
- And other new electromechanical developments.

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STAFF COLUMNIST

Jesse E. Hobson

Jesse E. Hobson is Vice President of the United Fruit Company

Tax Credits and Science

The sudden, but surely not entirely unexpected emergency created by the Russian sputnicks is occasion for a new examination of our nation's scientific effort. The sputnick's political and strategic significance has caused American citizens to look deeply and anxiously at our scientific resources, their management, and the goals which have been set for them. Up until this time the citizen has been satisfied to have his government and armed forces tell him that America's scientific strength and technological capabilities were unsurpassed. Now that these sources have been compromised by the Russian achievements, the country is calling upon its representatives for information and for action.

Both information and action are needed on many, many fronts, including education and training, personnel security, international political relationships and retaliatory capacity. But probably no field of action calls for more urgent attention than must be given to the problem of securing more adequate support for basic scientific research and education.

Basic research, the ultimate wellspring of our national productivity and standard of living, is also the source of our technological advance, our weapons systems, our defense capabilities. Far from being taken for granted, it must be nourished and cultivated assiduously so that new knowledge and new facts are available for the constant readjustments we must make to meet the pressing physical, social and political conditions of the world in which we live. Further, basic research is the training medium for competent and superior scientific manpower.

Sputnick, like every other feat of technological legerdemain, required years of the most painstaking, determined effort in basic and applied research. We must be prepared to provide financial support for greater effort in our own country, and we must find means by which our impressive resources of capital, talent and experience can be marshalled immediately for strong and effective action, in an environment appropriate for creative results.

Addressing themselves to this end, the executive and legislative branches of government are appointing committees and study groups, taking expert testimony, and considerng how to increase government appropriations and expenditures for science. Naturally enough, many see government agencies—the Department of Defense, the National Science Foundation, the Atomic Energy Commission—as the most suitable channels for direction and control of funds for scientific research. The funds are collected, of course, through other government agencies.

But government is an expensive and not too efficient middleman. No matter how often or how much the flow of dollars through government is increased, far too large a share slips off into superfluous overhead or into bureaucratic empires. Government, we should know by now, is not an effective shopper for talent. As scientific manager over the past decade or two government has been partially successful but it has brought us to the unhappy point at which we now find ourselves.

Our national science policies have not been entirely adequate. Our philosophy and our plans must be reformulated, redirected and invested with a renewed sense of urgency. Paramount among them is the necessity to develop means to secure and to insure that our best creative scientific minds have the freedom and opportunity to devote their talents to basic research. A revised national science policy, which is to say a national frame of mind, an attitude of government and of the governed as well, must create and maintain an atmosphere in which fundamental scientists of the highest caliber are encouraged to think, explore and experiment, to push back the boundaries of the unknown, to discover new facts and new knowledge for defense, for industrial applications and for humanity. Competent minds must be encouraged and stimulated toward advanced education and research.

In the present crisis, dollars become decisively important to such a policy. The need is recognized. Government is tempted to meet the need by its classic recourse to increasing and rebudgeting tax monies. This is necessary but not sufficient. The need today is not alone for more Washington administration of more dollars and more scientists, but for a more effective and efficient flow of na-

tional wealth to the laboratories and libraries of basic science, where the funds can be put to work without outside direction and control.

It has been suggested (first, I believe, by the late Dr. Frank B. Jewett) that provision for direct support of research by industry, by-passing government, would offer just this. Taxes on the profits, employees and property of industry are already the major support of government-conducted research. Direct payment by industry to universities, nonprofit institutions and other centers of basic research, payment unencumbered by the delays and overhead costs of government administration, would increase significantly the net amounts available for scientific undertakings.

Such support could come from industry as a direct credit against tax payments on corporate profit.

The core of the proposal is that industry's contributions to basic research and education would be regarded as a reduction in computed tax, rather than as an item deductible from income. Evidence of contributions to approved scientific, educational and public service research institutions, to a limit of perhaps 5% of computed tax, would be accepted by government as a credit on final tax payment. This credit, somewhat similar to the depletion allowance used by producers of petroleum and other minerals (although they are allowed 27.5% of gross income) would help to supply greatly increased dollar amounts necessary for expanded basic research and education programs.

Industry could not expect or receive any return or "favors" from its allocation of tax credit funds to institutions of education and research, but it would have the freedom to select the institution or institutions which would receive this assistance.

A company having computed corporate income tax of ten million dollars, for instance, would pay nine and one-half million to the Bureau of Internal Revenue. The remaining one-half million would be handed directly to universities or other approved not-for-profit public service research organizations. Properly certified proof of the payment would satisfy the Bureau that the company's tax obligation had been discharged. The tax credit policy might also be extended to individual income tax returns.

This re-routing of federal tax remittance, given unconditionally to the public benefit and without private return or quid pro quo of any kind, would assure greater support to science and education than can be achieved through government collection, distribution and control of equal funds. It would provide industry with far greater incentive to make such contributions than it now has. Implemented soon, the tax credit mechanism would be an active response to an urgent national demand. It would recognize that the depletion principle, by any realistic definition, applies as much or more to resources of scientific knowledge than to resources of petroleum.

The tax credit could, moreover, become the basis for long-range, permanent basic research and education support policies of both private enterprise and government. It could become the stimulus for creation of national scientific centers or a complex of basic research laboratories patterned after the great Kaiser Wilhelm Institutes or the laboratories of the Max Planck Societies of Germany, where exhaustive and productive fundamental studies in several fields are followed. President Eisenhower acknowledged in his recent Oklahoma City speech that basic knowledge cannot be created by emergency measures. It can, however, be encouraged, fostered and stimulated by progressive policies, both public and private, which is the sole objective of the proposed tax credit plan.

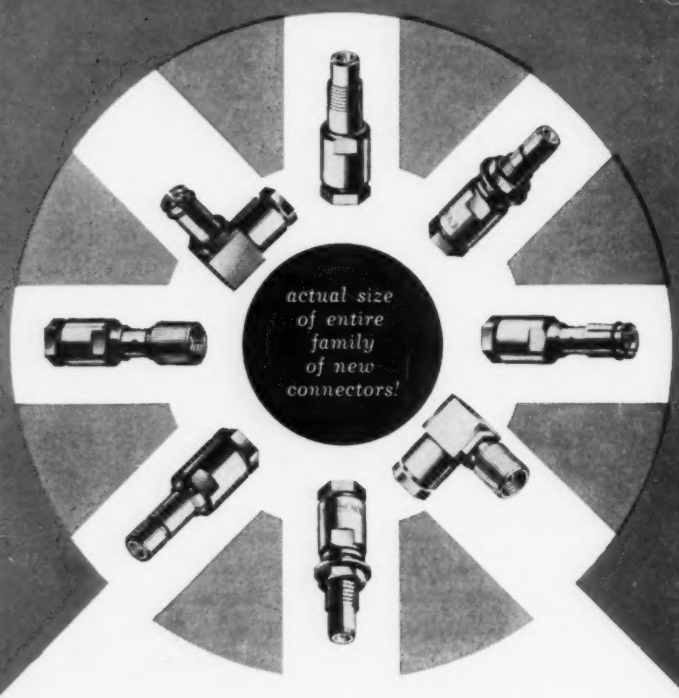
The program presented here in no way affects the control of military funds or the direction of weapons research, defense planning, missile and rocket development. The Department of Defense, the Atomic Energy Commission, their sub-agencies and other national agencies would continue—and could, in fact, increase—their responsibility for national security and defense in pursuit of powerful deterrents to insane military adventures by other nations. These are measures of defense which must be conducted and controlled by government. But government should not dominate the creative scientific resources of our country. (Government can and does, through the National Science Foundation, supply positive and extensive support for science and scientists. The Foundation's programs should be increased, if anything).

Tax credits, applying equally to profit-making concerns throughout the country, would also appear to encourage the broadest geographical distribution of scientific funds. Competition among universities for a greater share of tax credit dollars would inevitably develop. This prospect may dismay some people, yet the fact is that keen competition for research grants and corporate gifts exists already. Universities and scientific institutes would be put upon their mettle to develop the facilities and atmosphere in which scientific enterprise can thrive. If Slippery Rock State A. & M. can develop program and staff to compete for funds with our great, established institutions, the scientific community can only be benefitted.

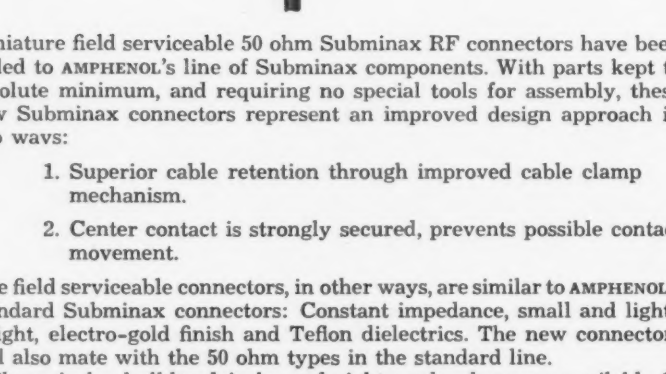
We stand today at a fateful point. Perhaps our survival and surely our destiny as free men are at stake. New national science policies, conceived in the urgency of this long-developing crisis, must be established. None will be more decisive than those affecting basic research effort. The tax credit proposal is presented again as one step toward assuring a more productive, positive development of this critical national resource.

field serviceable SUB*Minax*

RF CONNECTORS



for RG-196/U Teflon* Subminax cable



Miniature field serviceable 50 ohm Subminax RF connectors have been added to AMPHENOL's line of Subminax components. With parts kept to absolute minimum, and requiring no special tools for assembly, these new Subminax connectors represent an improved design approach in two wavs:

1. Superior cable retention through improved cable clamp mechanism.
2. Center contact is strongly secured, prevents possible contact movement.

The field serviceable connectors, in other ways, are similar to AMPHENOL's standard Subminax connectors: Constant impedance, small and lightweight, electro-gold finish and Teflon dielectrics. The new connectors will also mate with the 50 ohm types in the standard line.

Plugs, jacks, bulkhead jacks and right angle plugs are available in screw-on and push-on coupling designs. For complete part numbering and assembly instructions, send for catalog sheet.

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LETTERS

CORRECTION

Menlo Park, California

The Nov-Dec Issue carried a description of the Institute's Flash X-ray work.

However, there was an error in the story which has resulted in a number of letters from your readers. . . . The article stated: "Two X-ray tubes coupled with a high speed camera . . ." There is no high speed camera associated with the system. The film is exposed directly by the x-rays and a shadowgraph is the result. Further modifications and improvements are being studied. Improved penetration, more exposures of shorter duration and longer tube life are the present goals.

Otherwise the article was well received here. Judging from the quantity and quality of the letters motivated by this article, ELECTRO-MECHANICAL DESIGN is off to a flying start.

Charles Elkind
Stanford Research Institute

• • •

TRANSLATIONS

Syracuse, New York

In your Nov-Dec Issue on page 12 you invite comments as to possible interest areas in making translations of Soviet, German, French and other foreign research documents. We would like to see coverage in general, of the communications field which includes: modulation and demodulation, oscillation, coding and decoding, bandwidth compression, information theory, switching circuits, antennas and transmission lines.

If you intend to narrow your coverage to electromechanical subjects then within the above fields we suggest that attention be given to: microminiaturization as applied to connections—wire to wire, unit to unit; transducers—electrical to mechanical; electromechanical band pass filters; electromechanical resonant devices—audio to RF.

Within the electromechanical field your magazine has great possibilities and is off to a good start.

R. P. Gifford, Manager
Advanced Engineering
General Electric Company

• • •

Detroit, Michigan

I have just read your first issue and I would like to congratulate you on creating a magazine which so directly fills the need for a periodical covering this area of work. . . .

J. Wittenberg, Supervising Engr.
Chrysler Corporation

(continued on page 78)

←CIRCLE 3 ON INQUIRY CARD

ANALOG COMPUTER

New Component Simplifies Problem Solving

Problems facing the designer of analog computers have in the past forced serious compromises. Out of these compromises two principal philosophies of analog computing have evolved: The *unit operator* approach[1] and the *summing amplifier and potentiometer* approach[2].

A new computing component, the Universal Linear Operator (Figs. 1 and 2) developed by George A. Philbrick Researches, Inc., constitutes a third approach which, its designers say, combines and adds refinements to the earlier techniques to avoid their compromises. Mr. Daniel Sheingold who sent us information on the unit stated that its principal application is in the solution of sets of differential equations, such as those encountered in the design of electromechanical systems, where a high degree of economy, rapidity and flexibility of time scale are desirable. Examples of the three approaches applied to the setup of a simple second-order differential equation are shown in Fig. 1.

In discussing the relative merits of the three approaches, Mr. Sheingold said that the serious disadvantage of unit operators is multiplicity of operational elements, each of which involves at least one operational amplifier. This multiplicity imposes severe penalties in cost and accuracy. However, unit operators have the advantage of being independent from the standpoint of loading; they also have the important conceptual advantage that their configuration for a given problem is obvious even to many individuals not experienced in electronics or physical science.

A principal disadvantage of conventional summing amplifiers, according to Mr. Sheingold, stems from the loading of multiple-turn potentiometers by the amplifier input circuits. This potentiometer loading error imposes the requirement of either precision calibrators, which include reference power supplies, digital voltmeters, and elaborate switching, or of using calibration curves. He pointed out that neither solution is satisfactory because of the waste of time, especially if coefficients are to be readjusted while a problem is being solved. Also, the maximum coefficient of which a potentiometer is

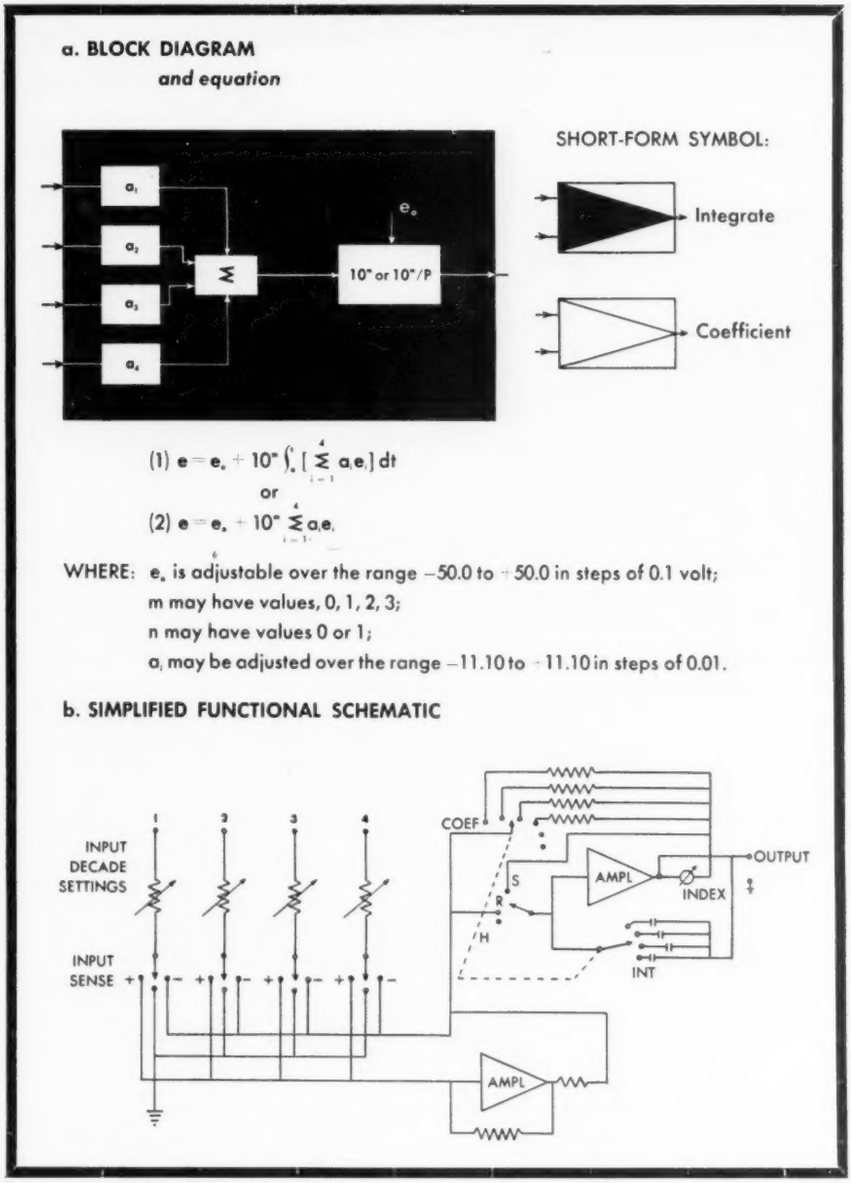

FIG. 2—The Universal Linear Operator is a drift-stabilized analog computing component that accepts up to four input voltages, applies to each an adjustable coefficient, and obtains the sum. The sum is then multiplied by an adjustable power of ten, either integrated or not as required and added to an adjustable index value, which serves as an initial condition in integrating. The coefficients a_i are set by three decade switches, one for each digit, as in 3.89. A fourth switch is used to set the sense of a_i—plus, zero, or minus. Thus, a given input voltage may be added, subtracted, or removed entirely by operating a switch. After being summed, the weighted input voltages are either integrated or amplified. For integration, a choice of integrating speeds from 1 to 100 radians/second is available in steps of powers of 10. For amplification, a choice of gains from 1 to 1000 volts/volt is available in steps of powers of 10. An index voltage, adjustable in the same manner as the coefficients a_i, is either added directly to the output voltage when the unit is used as an amplifier or applied as an initial condition when it is used as an integrator. Internal relays to set initial conditions or to hold problems may be operated either from a switch on the front panel of the component or remotely from a master control. Lamps on the front panel indicate excursions which exceed rated maximum output voltage, and an internal circuit prevents amplifier offset due to such limiting.

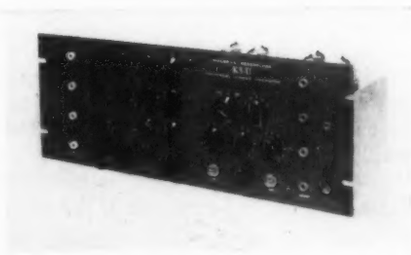

FIG. 1—Front Panel view of Universal Linear Operator.

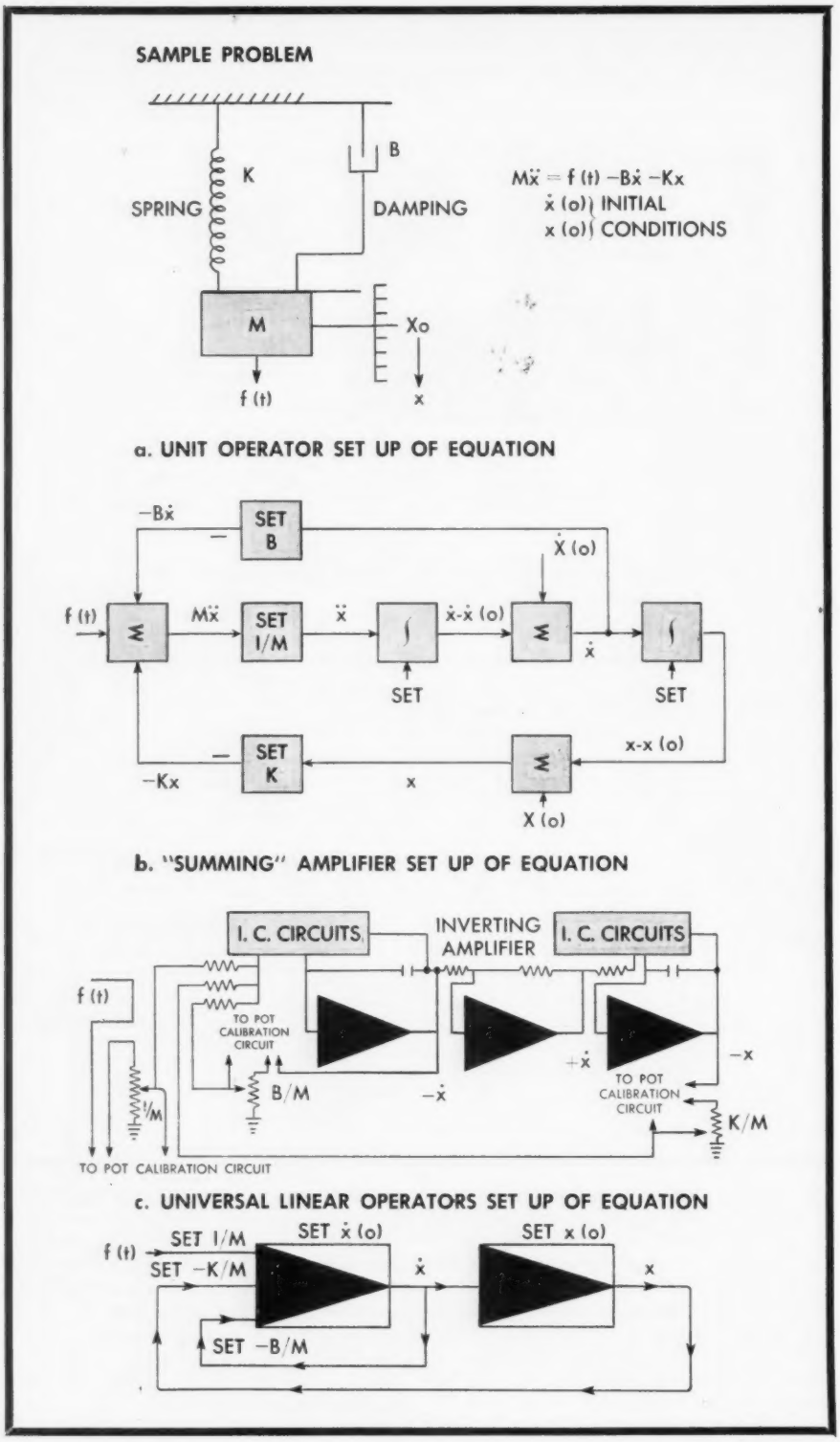

FIG. 3—Comparative treatment of a simple problem by the three analog computer techniques.

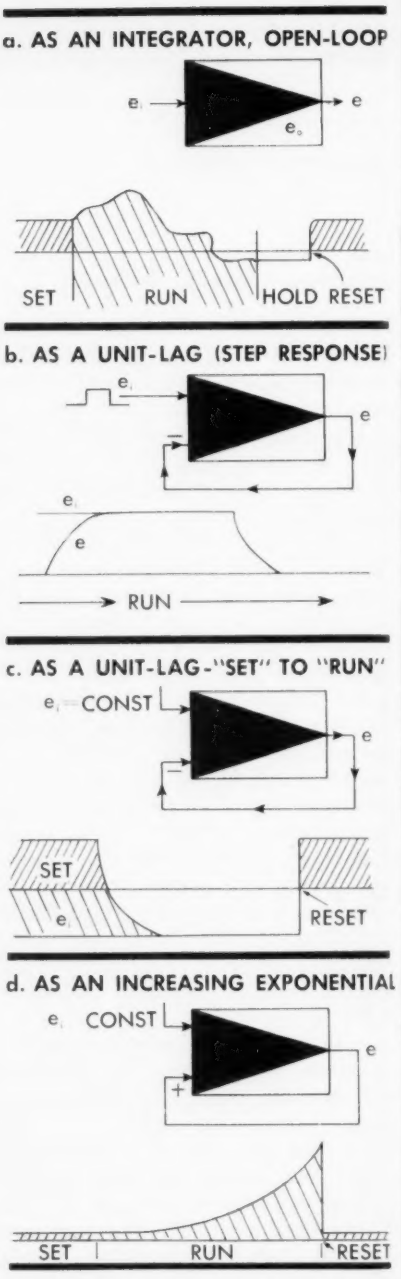

FIG. 4—Typical responses of the Universal Linear Operator for various modes of operation.

capable is unity. "Another difficulty with conventional summing amplifiers," he said, "is that their sense is inherently negative, necessitating the employment of inversion as an extra step if reversal of sense is desired. Thus, a number of elements in the computing structure must be reserved for inversion, and these extra connections complicate block diagrams."

Designers of the Universal Linear Operator state that their new component eliminates potentiometer loading errors by use of precisely calibrated three-dial decades for all parameter settings including coefficients and index voltages. Furthermore, they say that by retaining the essence of unit operations in a much more compact form, and by allowing sense to be an inherently adjustable parameter of each input, this component is a flexible and powerful tool in the solution of problems by analog computing. Figure 4 illustrates typical responses of the unit for various modes of operation.

Repetitive high-speed computing as well as conventional "real-time" or "slow-time" computing are inherent features of the unit made possible by the use of chopper-stabilized amplifiers with open-loop unity-gain bandwidth of greater than one mega-radian/second. Reliable relay switching, controllable either locally or remotely, is used for operating the SET-RUN-HOLD modes. For ease in servicing, the unit is designed to operate with plug-in d-c amplifiers and plug-in relays.

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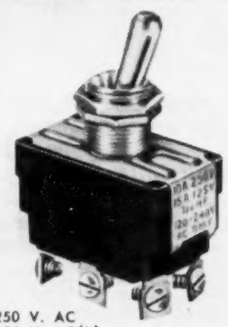

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15 Amp. 125 V. AC(L)
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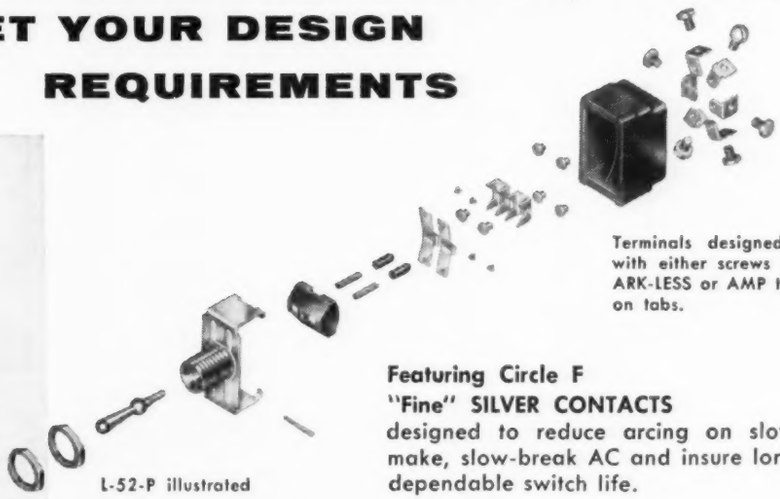

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6A - 125 V
3A - 250 V

L-42-E
S.P.D.T.
on-off-on

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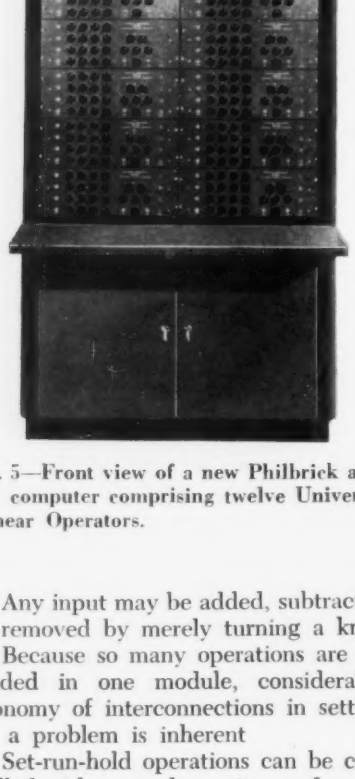

FIG. 5—Front view of a new Philbrick analog computer comprising twelve Universal Linear Operators.

- Any input may be added, subtracted or removed by merely turning a knob
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APPLICATIONS

Three typical applications of the new unit to linear systems of interest to electromechanical designers are shown in Figs. 6, 7 and 8. It may also be used with standard types of nonlinear operators to solve the usually more interesting problems that involve nonlinear elements.

1. *Unit operator notations and applications are described in "A Palimpsest on the Electronic Analog Art," G. A. Philbrick Researches, Inc., 1955. Examples of computer block diagrams in Figs. 6, 7 and 8 were based on problems described in the Palimpsest on pages 229, 139 and 78.*
2. *The summing amplifier and potentiometer method of computing is described in some detail in "Electronic Analog Computing," by Korn, G. A., and Korn, T. M., McGraw-Hill, 1956.*

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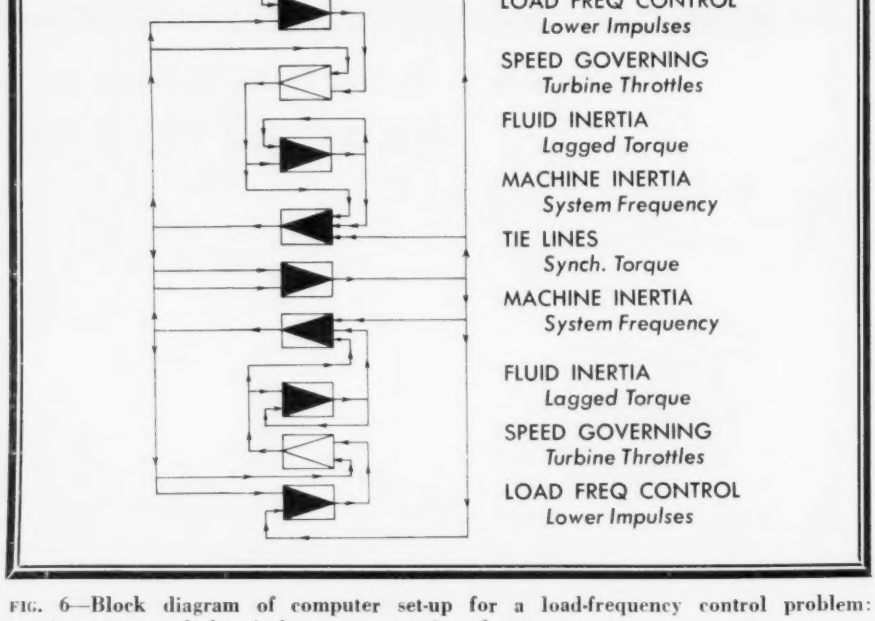


FIG. 6—Block diagram of computer set-up for a load-frequency control problem: two interconnected electrical power generating plants.

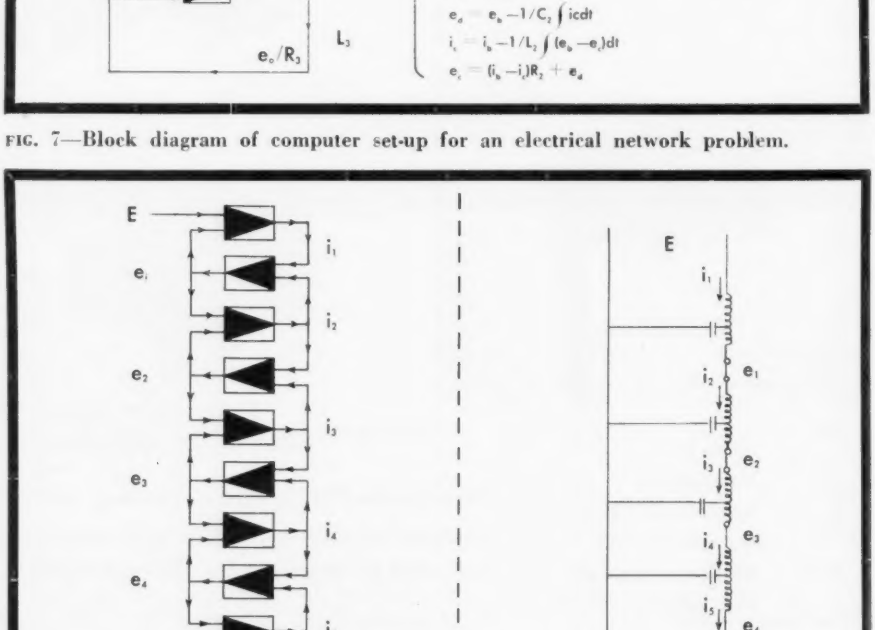


FIG. 7—Block diagram of computer set-up for an electrical network problem.

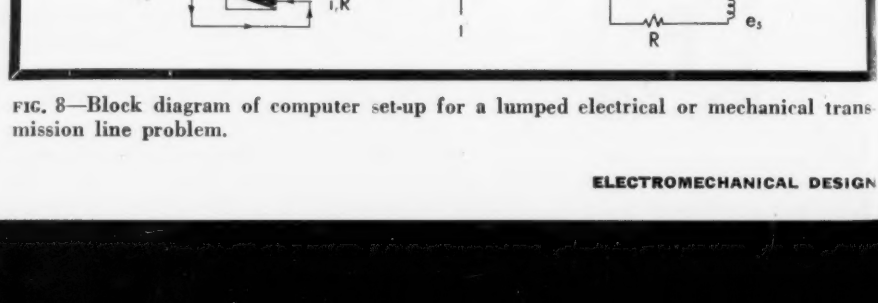
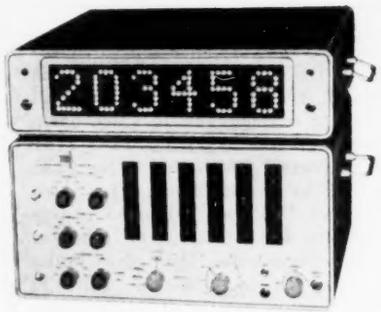


FIG. 8—Block diagram of computer set-up for a lumped electrical or mechanical transmission line problem.



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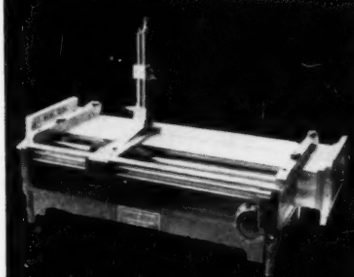

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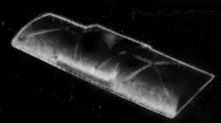

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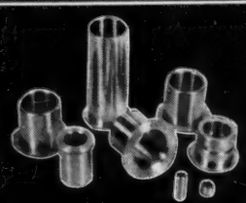

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HYDRAULIC VALVES

Pulse Length Modulation: A New Mode of Operation

Results of more than a year's experimental testing of a new principle in design of hydraulic valves for control systems were reported at the ASME Annual Meeting in New York City, December 1957. This principle, called pulse length modulation, constitutes a new mode of valve operation in which oil flow is controlled by opening the valve port full scale in alternating pulses of varying length proportional to the input signal, rather than by varying the port opening in proportion to the input. Figure 1 illustrates this principle.

The tests were carried out by J. E. Gibson, Assoc. Prof. of E.E., Purdue University; F. B. Tuteur, Assoc. Prof. of E. E., Yale University; and T. J. Mapes of Eastern Industries, Hamden, Conn. They reported "quite encouraging results." Valves designed for the proportional mode of operation showed greatly improved frequency response when operated in the PLM mode (Fig. 2). This fact, they pointed out, is interesting in view of the very high performance of these valves operated in the mode for which they were designed; but even more important, they said, is the fact that valves can be constructed to take full advantage of the new operating mode. Figure 3 is the outline drawing of the Yale No. 5 single-stage valve designed for PLM operation. The spool is a conventional three-land type, but the design of the solenoid was optimized for force per ampere and no attempt to linearize the force curve was made. The result is a compact, rugged single-stage valve.

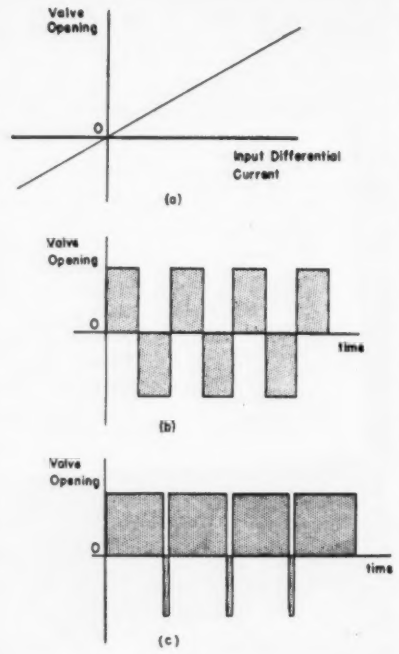

FIG. 1—Principle of pulse length modulation (PLM) operation of hydraulic valve. Fig. 1(a) shows the conventional ideal linear characteristic of valve opening versus input current. Fig. 1(b) shows valve-stem positioning in the PLM mode for no input signal. The valve stem is switched from full open in one direction to full open in the other at some repetition rate. The valve dwells equal times at each extreme and the average flow is zero. Fig. 1(c) shows a large signal case. Dwell time on one side is increased while dwell on the other is decreased. Average flow is proportional to the difference in dwell times. Electronic conversion of the proportional electric signal into a pulse-length modulated wave to drive the valve is relatively simple. The major remaining problem is that the load must be such that it can accept the pulsed form of valve output. Fortunately, practically all loads will smooth or average the flow quite satisfactorily, and in fact the second stage of a two stage valve provides considerable smoothing itself.

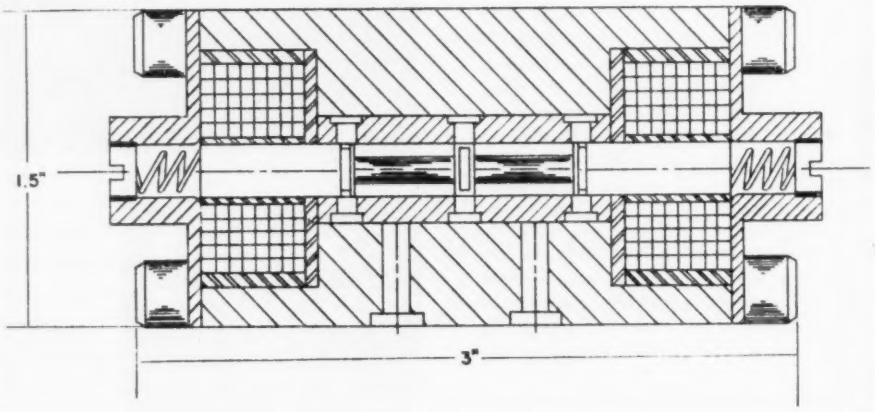

FIG. 3—Yale—5 single-stage PLM valve (full scale). Body contains single-stage spool-type 4-way valve and actuating solenoids. 2 gpm and 1000 psi.

RESPONSE OF SINGLE-STAGE VALVE

The magnetic amplifier driver for the Yale No. 5 valve has a pulse repetition rate of 400 cps. Wave shape of the mag-amp driver is shown in Fig. 4. Static response of valve versus amplitude of input voltage is shown in Fig. 5. The slight dissymmetry with respect to positive and negative signals is due to an offset in the porting of the valve and is not considered critical in this first experimental model. Given the pulse rate of the mag amp of 400 cps, absolute upper response frequency of the valve is 200 cps with a practical upper limit of 150 cps. This response is adequate for most applications. For higher response the pulse repetition rate could be increased. Figure 6 shows the frequency response of the valve. Note that the response is absolutely flat to well above 100 cps.

The experimenters concluded from their tests that the PLM mode appears to provide an advance in the hydraulic control art; it is a radical approach to the problem that holds much promise. The tests proved to them a single-stage valve is practical, the driver and soleniod configuration are not so complex as to be prohibitive, and the frequency response of the valve is superior to that of any conventional valve available at the present time.

ADVANTAGES OF PLM MODE

The authors pointed out several additional advantages of the PLM mode:

1. The torque motor or electric actuator of the valve may be optimized for maximum force per ampere. If the

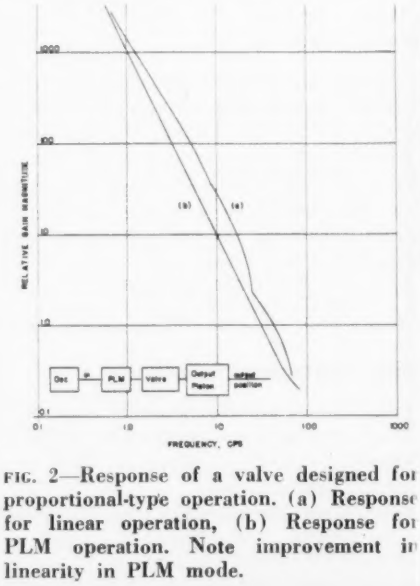

FIG. 2—Response of a valve designed for proportional-type operation. (a) Response for linear operation, (b) Response for PLM operation. Note improvement in linearity in PLM mode.

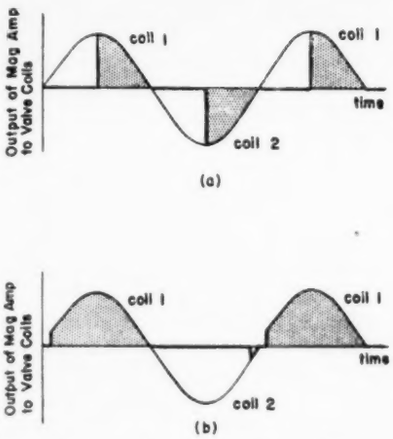

FIG. 4—Wave shape of mag-amp-driver; alternate pulses to one solenoid.

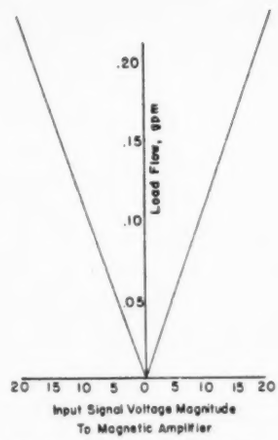

FIG. 5—Static response of Yale No. 5 valve.

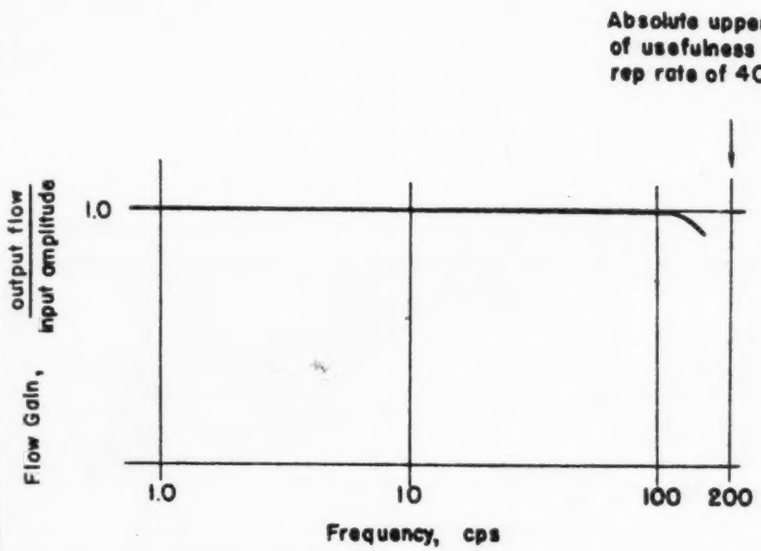

FIG. 6—Frequency response of Yale No. 5 valve; pulse repetition rate is 400 cps.

esponse of the torque motor must be made a linear function of current, as is attempted in conventional valves, the efficiency must be sacrificed in order to obtain this linearity. In the PLM mode the electric actuator may thus be made smaller and more efficient.

2. In the conventional valve, the flow gain is usually reduced at small signal amplitudes. This is not true in a PLM valve.

3. Small signal sticking may be eliminated, since in a sense the PLM mode provides a massive valve dither.

4. Small opening Bernoulli forces are unimportant in the PLM mode.

5. Valve lock is a less serious problem because the valve spool is kept in motion and because it is not necessary to design for exceedingly small clearances. Furthermore, the electric actuator can be designed to provide a high opening force.

6. Manufacturing tolerances may be relaxed. Since the premium on precise linearity of flow versus stroke no longer holds, the valve tolerances may be opened up by a considerable factor and still yield satisfactory performance. For instance round valve ports are perfectly adequate, rather than slots.

7. Since the torque motor may be optimized for maximum force, it becomes practical to design a single-stage valve, doing away with the hydraulic preamplifier usually used. The resultent single-stage valve is more economical. There is some increase in the complexity of the circuit used to drive the valve. Fortunately, however, the PLM modulator may be constructed with only a few vacuum tubes, or a magnetic amplifier may be used.

LIMITING FACTORS IN PLM MODE

Several limiting factors in the PLM mode of operation were indicated by the tests. First, the pulse repetition rate must be set as high as possible so as to achieve the maximum frequency response for the valve. The forces required to accelerate the spool demand a rather heavy solenoid design if full rated flow is to be obtained at high repetition rates. If sufficient force is not available from the solenoid, the valve will still operate properly but with a reduced flow gain. This feature of gradual reduction to zero rather than abrupt failure in the face of reduced driver input would be a factor in reliable operation in the field.

Internal leakage flow to the sump at null is not zero. In this particular model the null flow is about .05 gal/min. A certain amount of null leakage is inherent in the PLM mode but this figure compares favorably with two stage flapper valves of the same power rating.

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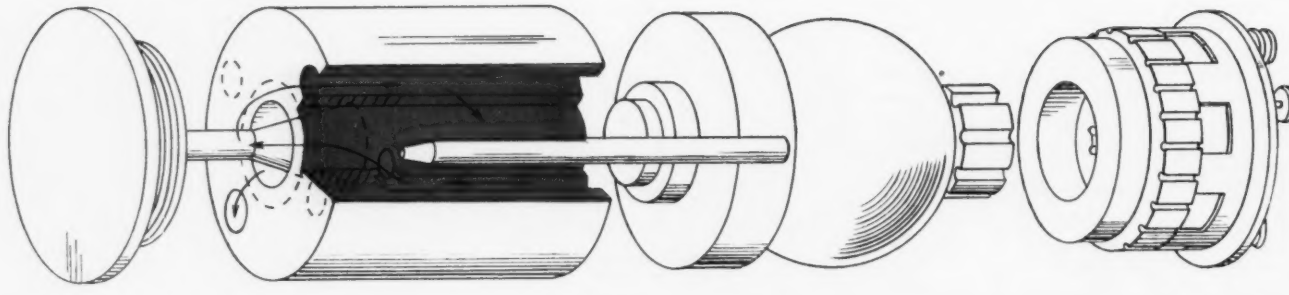

FIG. 3—Sketch illustrating operation of damper. The major components of the damper mechanism are a lightweight paddle ring, a damping block, a piston, and a temperature-sensitive bellows. Movement of the paddles through the fluid in the damping block provides the damping action. To minimize effects of variations in temperature, the piston, positioned by the temperature-sensitive bellows, varies the resistance of fluid flow in the damping block by changing the area of the orifice through which the fluid flows. As the viscosity of the fluid changes with temperature, the paddles encounter an essentially constant back pressure regardless of temperature and velocity, thus maintaining the desired damping ratio.

RATE GYRO

Dashpot-type Damper Design Minimizes Temperature Dependence

One of the more important problems for which better solutions are constantly being sought is that of providing a constant damping ratio over the desired operating range of a floated rate gyro.

As an answer to this problem, Sanders Associates, Inc. of Nashua, New Hampshire, have recently developed a new and simple damping mechanism which, they say, approaches the ultimate in damping characteristics. This unique device designed into their model RGB subminiature rate gyro maintains a nominal damping ratio variation of only ± 0.1 over a relatively large operating temperature range of -25 to $+100$ degrees Centigrade (Fig. 1). Figures 2 and 3 illustrate and describe the dashpot-type damper technique used to obtain this essentially flat damping characteristic. Details of the design and some of the design considerations were described for us by Edward Eckhardt of Sanders.

At high operating temperatures, where viscosity of the fluid is low and orifice area is minimum, effective damping is maintained by the fact that the leakage gaps between the high and low pressure areas are as small as possible. Under these conditions, leakage flow is sufficiently small to provide effective damping beyond the compensating temperature range of the variable orifice.

Effective damping at low operating temperatures, where viscosity of the fluid is high and orifice area is maxi-

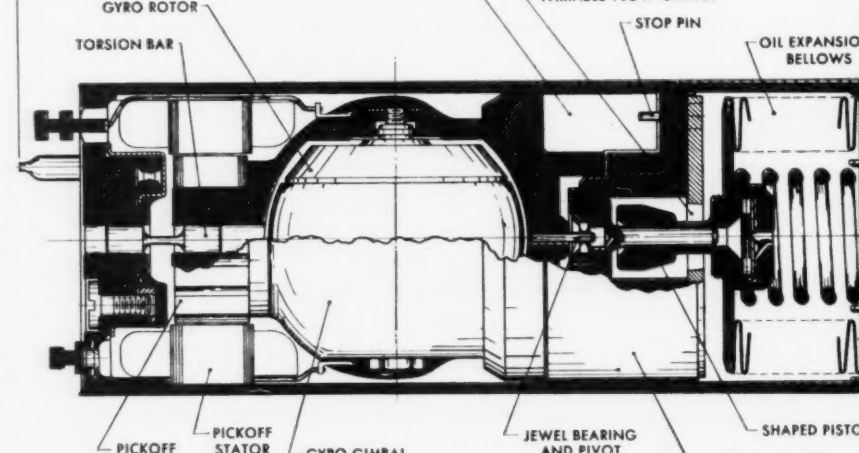

FIG. 2—Cross section drawing of gyro showing damper parts.

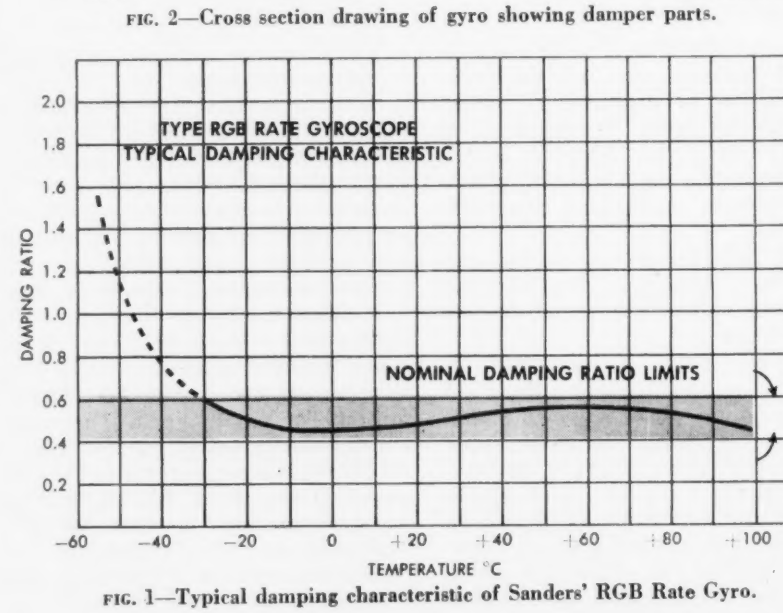

FIG. 1—Typical damping characteristic of Sanders' RGB Rate Gyro.

mum, is maintained by insuring that shear-damping action contributed by gyro components other than the paddles is not excessive.

Flatness of the damping ratio curve, between the two extreme operating temperatures, can be attributed to care and accuracy in manufacturing the piston, as well as control of leakage-gap areas in both assembly and manufacturing processes.

Since the paddle ring is fastened to the gimbal, it is essential that the paddle ring be fabricated from a lightweight material, such as aluminum, in order to minimize moment of inertia about the gyro's output axis and to retain the high natural frequency inherent in subminiature rate gyros.

A guide pin is used for the piston to insure that the piston is concentric with the orifice at all times and prevent errors in damping at high temperatures, as a result of eccentricity with respect to the orifice.

The preferred design of this damping mechanism uses a jewel-pivot bearing and rotating shaft assembly, rather than a second torsion bar, for the support of the gyroscopic element. This construction increases the ability of the gyro to withstand vibration and shock forces. Compared to a gyro that uses a dual torsion bar supporting system, the RGB rate gyro withstands nearly twice the vibration and shock forces since the torsion bar stiffness is doubled for any given full scale rate.

With dashpot dampers, laminar flow through the orifice is preferred for developing a damping force that is proportional to velocity. According to Kenneth Mayo, who did the analysis for the design, both calculations and experimental verification data have proven conclusively that turbulent flow does not occur.

With very high speeds and damping factors, it is theoretically possible to drop the pressure of the fluid and cause cavitation. Mr. Mayo states, however, that in the RGB rate gyro the precessional velocities encountered cannot cause cavitation since the vapor pressure of the silicon damping fluid and gyro precessional forces are sufficiently low.

Even though the damping characteristics of Sanders' RGB rate gyro are superior to their original RGA model, the cost to the customer is only slightly higher. "This fact," Mr. Eckhardt said, "can be attributed to the simplicity of the damper design, which avoids objectionable cams, levers, and linkages, and to the fact that a large percentage of the original design was used, retaining many of the desirable operating characteristics and the reliability of the time-proven earlier model."

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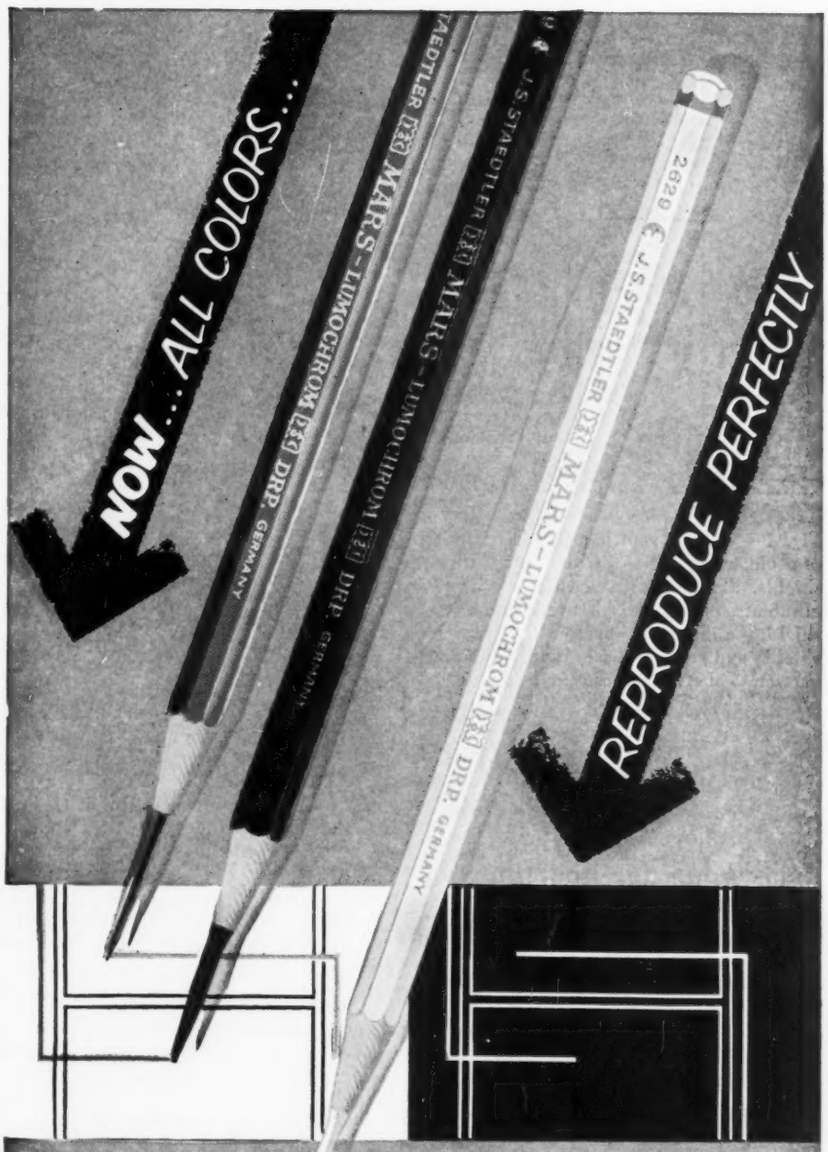

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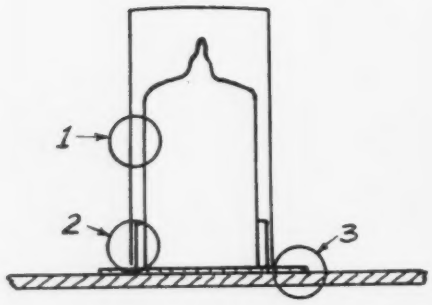

Fig. 1— Sketch showing thermal barriers of electron tubes with conventional shields. Shield shown in Fig. 2 virtually eliminates barrier 1 between tube and shield, eliminates barrier 2 between shield and shield base, and minimizes barrier 3 between base and chassis.

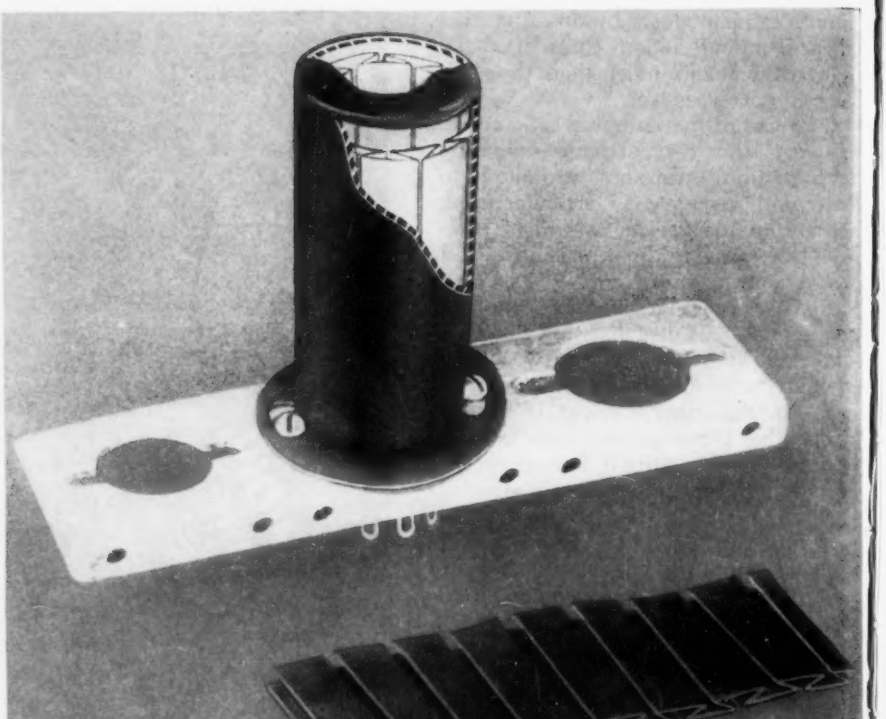

Fig. 2—Photograph of Atlas E. E. Full-Contact Insert and One-Piece Shield retouched to show arrangement of insert in shield. Insert contacts between 95 and 98 percent of the tube envelope surface to conduct heat from tube to shield. Shield and base are one piece and base is as flat and large as possible to maximize heat flow to the chassis. Double headed screws supplied with the shield hold the tube socket in place under the chassis. The shield twist-locks in place on the two screws. It is easily adapted to existing equipment merely by replacing the two screws that hold the tube socket with the special double headed screws.

ELECTRON TUBE RELIABILITY

New Heat Conducting Shield Prolongs Tube Life

The U. S. Naval Research Laboratory has given wide publicity to damage being caused by use of JAN TS electron tube shields which set up a thermal barrier between tube and shield creating a dead-air space. The barrier, they said, increases the envelope temperature of the tube well above the danger point resulting in high failure rate. These findings, resulting from extensive investigation of temperature effects on tube life, lead to a series of developments by N. E. L. to improve tube shields. Implementing these developments, Atlas E. E. Corporation of Woburn, Mass., has designed a One-Piece Shield incorporating a Full-Contact Insert which conducts a large percentage of the heat from the tube envelope down through the tube base into the chassis. The designers state the new shield reduces the temperature of the tube by more than 100 degrees C, whereas an S-28 shield increases tube temperature by about 40 percent.

Figure 1 shows the thermal barriers that obstruct dissipation of heat from tubes with conventional shields. The Full-Contact Insert virtually eliminates barrier 1 by making contact between the shield and 95 to 98 percent of the tube envelope surface. The One-Piece Shield gets rid of thermal barrier 2 by making the shield and base as one unit, and minimizes barrier 3 by making the surface of the shield base as flat and large as possible to increase contact area without causing interference. Figure 2 is a photograph of the insert and of the shield locked in place on the chassis. Both units are adapted for use in existing equipment.

BACKGROUND

Realization of thermal inadequacy of the JAN S-28 shield led to development of the Type-B improved shield described in military specification MIL-S-9372. Type-B shield takes heat from the surface of the tube by means of a finger-type liner, which provides horizontally and vertically symmetrical rows of contact areas contacting between 35 and 40 percent of the tube envelope surface. This shield reduces bulb temperature by 60 degrees C or more (Fig. 3), but it is not suitable for retrofit because it requires a non-standard base.

In October 1956 the Navy Electronics Laboratory issued a supplement

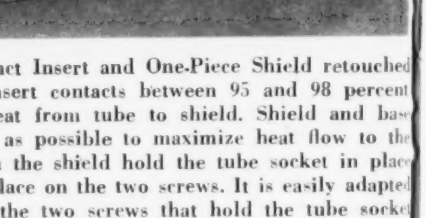

Fig. 3—Curves showing efficiency of various shield and insert designs in reducing electron tube temperatures.

to their Reliability Design Handbook describing their design of a corrugated insert for use in TS shields. The square-wave-type insert increased contact area to about 50 percent of the tube envelope surface, and reduced the bulb temperature by about 50 degrees

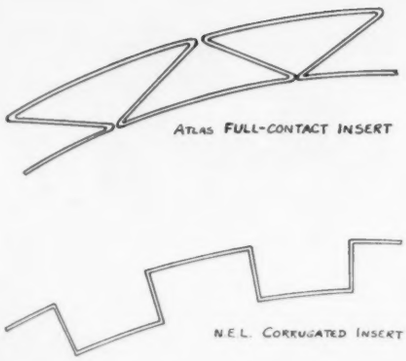

Fig. 4—Cross sections of Atlas Full-Contact Insert and Navy Electronics Lab. Corrugated Insert illustrating contact areas of the two designs.

C or more (Fig. 3). It had the advantage of being adaptable to existing equipment. N. E. L. received reports of spectacular results in prolonged tube life by users of corrugated liners.

Atlas E. E. engineers carried the design of the N. E. L. liner a step further to obtain their Full-Contact Insert. Figure 4 illustrates the increase in contact area of the Atlas insert over that of the corrugated unit.

Having reduced the thermal barrier between tube and shield, N. E. L. turned their attention to the other barriers. First they performed experiments to determine whether the shield would conduct heat better with or without side openings. They found that a shield with no windows gave increasingly better cooling as ambient temperature increased. Accordingly, they designed a solid shield using a corrugated liner and the same base as in the Type-B shield. Tests of this unit showed a reduction of bulb temperature 30 degrees C below that of the Type-B shield, as indicated by the curve marked "NW-corr. liner" in Fig. 3. N. E. L. then eliminated the thermal barrier between the shield and base by soldering the shield to the base. This technique further reduced bulb temperature by 20 degrees C, as shown in the curve marked "special" in Fig. 3. Results of these experiments were presented to the Reliability Conference at Syracuse, New York, June 11, 1957.

Atlas E. E. following the results of these tests closely, initiated design of a shield that would take full advantage of the N. E. L. experiments, but which would also incorporate their own Full Contact Insert and be easily adaptable to standard equipment. They claim that their final design shown in Fig. 2 reduces bulb temperature 10 to 20 degrees C below the curve marked "special" in Fig. 4. This difference, they say, is achieved by use of the Full Contact Insert.

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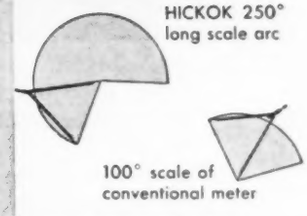

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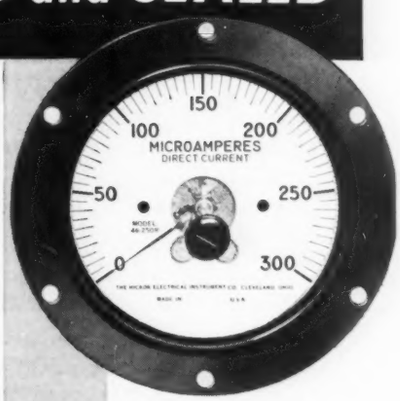

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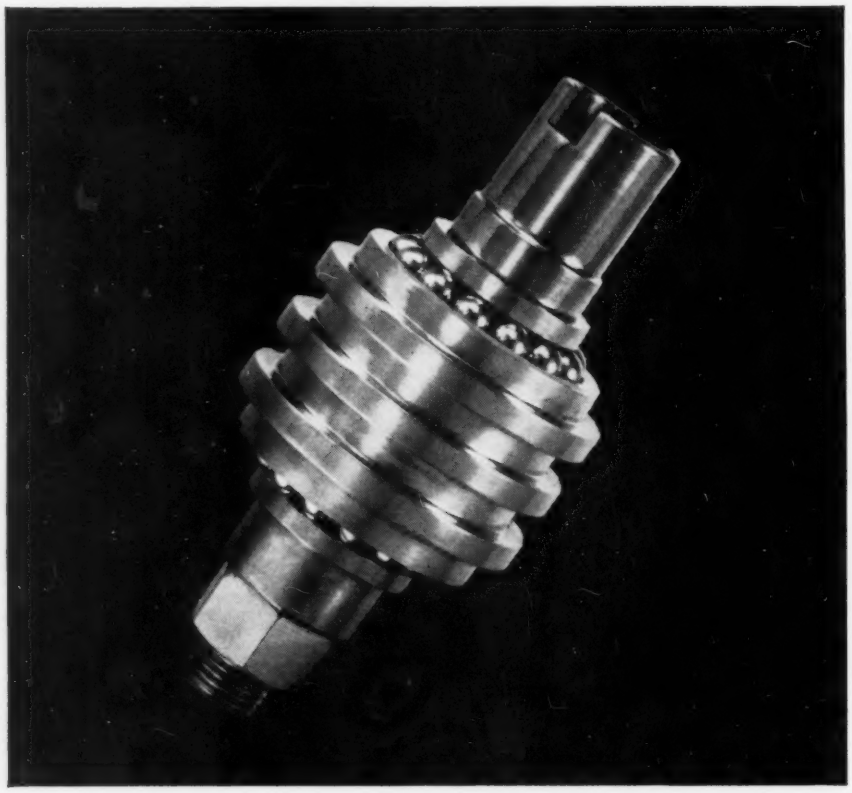
FOR MORE INFORMATION CIRCLE 8 ON INQUIRY CARD

Dual-Purpose Ball Bearing Solves Tough Design Problem



Anti-friction bearings made for specific applications free the designer from the limitations imposed by "standard" bearings, and permit a better product at lower cost. These advantages are demonstrated by the bearing shown above, which is used in an atomic reactor control mechanism. Consider the following features:

- The outside diameter has a tooth form that engages a lead screw. This saves the space, weight and cost of separate parts that would otherwise be required, and avoids variations resulting from a "stack-up" of tolerances.
- The bearing runs in hot water under pressure, at 350°-500° F.; and the water is its only lubricant.
- It withstands the corrosive action of high-purity water at the required operating temperatures.
- Low torque is essential; and dependability throughout a long life is of vital importance.

We obtained the required characteristics through the use of special alloys, and through very close control of bearing geometry, dimensions, and surface finish.

In similar ways, we have helped improve the design and performance of hundreds of other military and industrial products. If *you* need special anti-friction bearings for *any* purpose, let's talk it over. ***Bulletin on request.***

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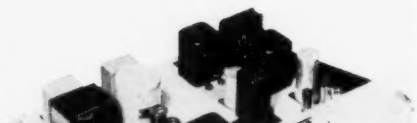


Rate-Of-Change Computer Measures Low Level D-C Signals

A new rate-of-change computer measures slowly varying, low level voltage changes—from 10 to 5000 microvolts/second, superimposed upon static voltages from 0 to 100 millivolts. The computer readout is a d-c voltage proportional to the rate of change measured and is suitable for operating any standard recording potentiometer. A selector knob permits a choice of six full scale output ranges, from 100 to 5000 microvolts/second. Faster rates are also possible. Input power for operating the computer is standard 115 volts, 60 cps. The complete computer package includes a high-gain d-c differential chopper amplifier with completely floating high-impedance input, an electronic rate unit which performs the computing, a transistorized 400 cps power supply for the choppers, and a regulated d-c supply. The unit is compactly packaged—7 inches high and mounts in a standard 19-inch relay rack. The Model 0557-1 is designed for a variety of instrumentation programs involving nuclear reactors, petrochemical processing, and aircraft and missile equipment. Typical applications include measurement of temperature build-up in nuclear reactors where as little as 0.5 degrees F/sec can be detected, measurement of neutron flux change in reactors and slow pressure changes from strain gage pressure transducers. *Magnetic Instruments Co., Thornwood, N. Y.*

Circle No. 194 on Inquiry Card

WORTH FILING

Steel Dictionary

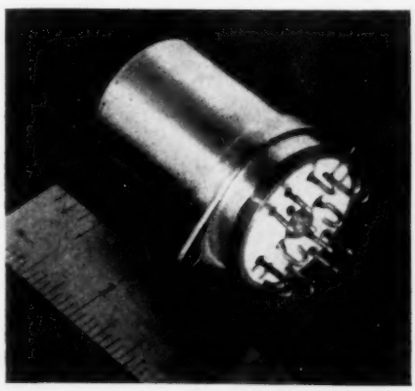
A 32-page dictionary of steel terms includes more than 180 relatively detailed definitions frequently used in the purchase, manufacture, treating, machining and finishing of steel. Terms defined range from annealing and austempering through isothermal quenching and macro-etching to spheroidizing, stress relieving and yield strength. More than 30 photographs, curves and tables.

Source: LaSalle Steel Company
Chicago 80, Illinois

For your copy: Circle No. 165 on Inquiry Card

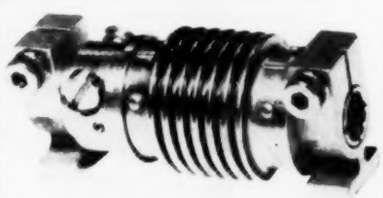
High Ambient Temperature Relay

A new miniature relay, which fulfills the Class C, Type II, Grade 3 requirements of Specification MIL-R-25018, MS-24114-9, operates in an ambient temperature of +200°C, withstands in excess of 55G shock for 11 milliseconds, withstands 25G vibration up to 2000 cps, and a contact bounce of less than 250 microseconds. The relay has a 4-pole, double-throw contact structure, using bifurcated contacts to improve contact reliability in dry circuit applications and to increase the current carrying capacity of the contacts.



The relay will withstand severe thermal shock. The insulation is all ceramic material to insure that extremely high insulation resistance is maintained at maximum operating temperature. This type of insulation also insures that no volatile material will be liberated to affect contact reliability. The coil is hermetically sealed from the contact structure. *Union Switch & Signal, Division of Westinghouse Air Brake Co., Swissvale, Pennsylvania.*

Circle No. 184 on Inquiry Card



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Patented zero adjustable Bellows Coupling, available for "off-the-shelf" delivery, allows precision adjustment on sensitive shafts of servo motors, resolvers and synchros. It also is designed for 360° continual rotation and adjustment. Range of adaptability is for four (4) basic shaft sizes ⅛, 3/16, ¼ and 0.1200 to ⅛ and can be applied on pin- and clamp-type hubs. *PIC Design Corp., Sub. of Benrus Watch Co., Inc., East Rockaway, New York.*

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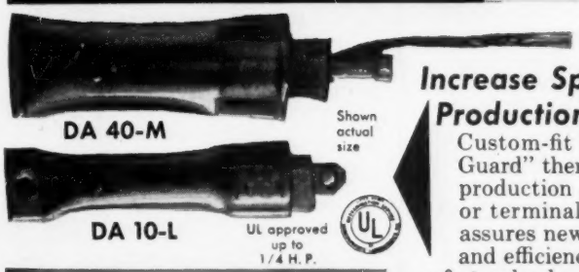

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Custom-fit uniformity of "Temp-Guard" thermostats assures *ease* in production line application. Leads or terminals to your specification assures new production line speed and efficiency. Many modifications of standard models — if one of these doesn't serve your requirements, we'll design one that will.

Write now for Dales' New Engineering Brochure. For emergency engineering assistance on temperature control problems, the Cessna 180 shown at left will bring Dales' Engineers to your nearest airfield.

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POSITIVE LOCKING . . .
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The Smith-Nobak Device permits both shafts to rotate simultaneously. When power stops, the device prevents further rotation of the mechanism either from the initial inertia force or from an external force applied from anywhere except the original source. The driven shaft is locked in position to prevent its rotation in either direction. Application of power unlocks the device instantly.

The device is finding numerous uses in automation, aircraft control mechanisms, hoists, transfer tables, conveyors, punch presses, printing presses, and wherever a positive control of angular position is required. It is especially adaptable for steering mechanisms of industrial trucks, tractors, and boats; for feeds into presses, and for boom hoists of derricks. Load ratings from 50# in. to 2600# in. are available. Specific recommendation will be sent you on receipt of your requirement.

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CIRCLE 11 ON INQUIRY CARD

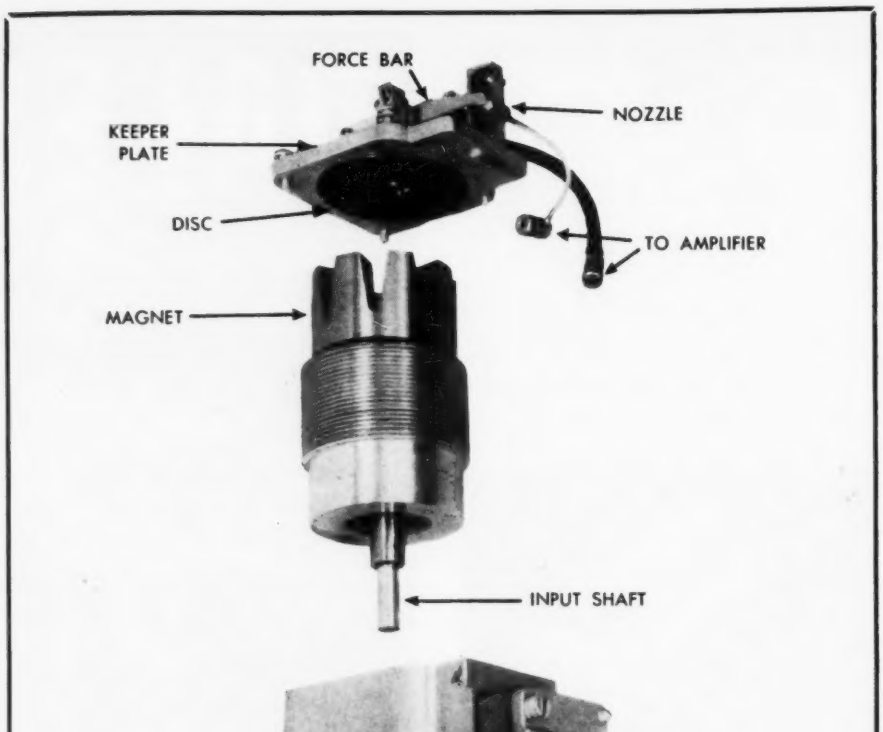
MACHINE SPEED CONTROL

New Means with Pneumatics

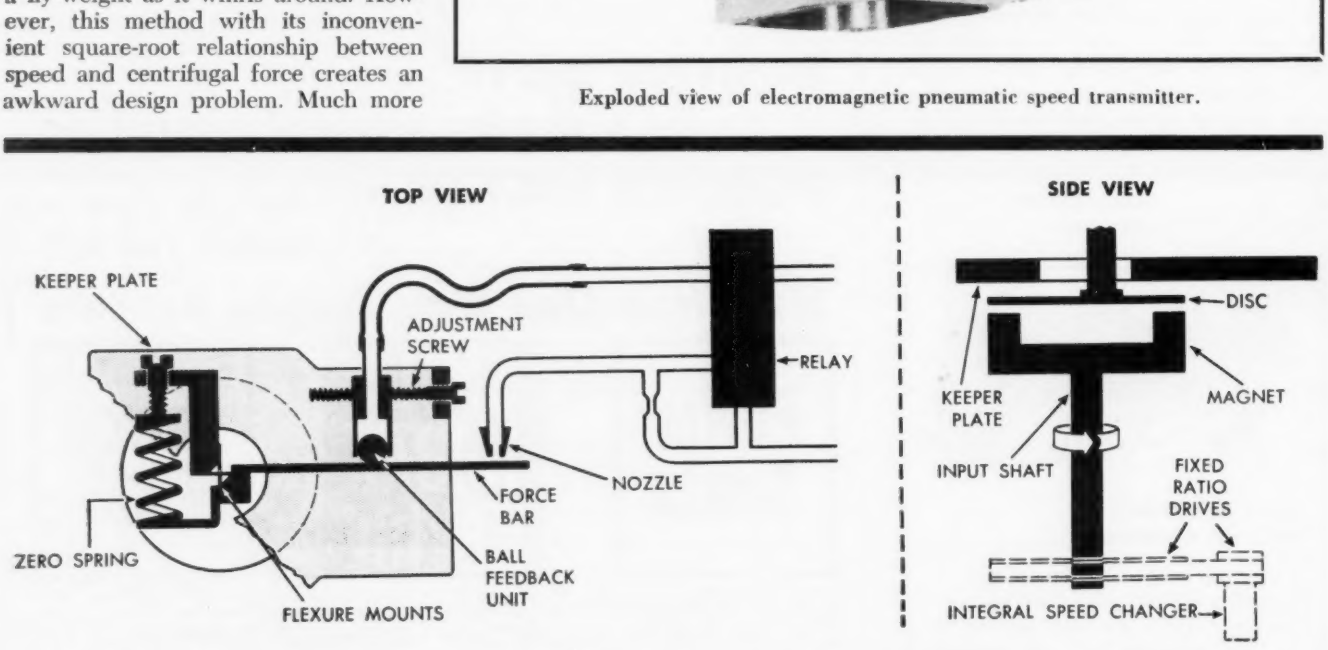
Speeds of rotation are converted linearly to useable pneumatic outputs in a new type of speed transmitting device. The design uses the output of a magnetomotive tachometer to regulate air pressure in a pneumatic amplifier for speed measurement, recording, and control.

Engineers of The Foxboro Company, Foxboro, Mass. were given the problem of designing an industrial speed transmitter that would compare favorably with others on the market and at the same time meet special requirements of their petroleum and chemical customers whose applications might involve potentially explosive or corrosive atmospheres. Another consideration was competition with the many existing designs of tachometer generators, vibrating reed indicators, and indicating tachometers on the market.

One of the best known principles for measuring angular velocity of a shaft is to measure centrifugal force created by a fly-weight as it whirls around. However, this method with its inconvenient square-root relationship between speed and centrifugal force creates an awkward design problem. Much more



Exploded view of electromagnetic pneumatic speed transmitter.



Operation of speed transmitter. The input shaft carries an eight-pole permanent magnet. A non-magnetic alloy disc of high permeability is positioned by flexure mounts between the keeper plate and the magnet poles. As the input shaft rotates, magnetomotive pull tends to turn the disc in the same direction. This pull positions the force bar attached to the disc in relation to the nozzle, causing an increase in back pressure in the air flow through the nozzle. This back pressure, amplified by the relay, produces an output pressure which is the 3-15 psig transmitted air signal. The output pressure is also connected to the ball feedback unit which rides against the force bar producing a moment to balance the torque on the disc produced by magnetomotive pull. The feedback unit is a small, open-ended cylinder with a ball acting as a free floating piston with spring action. Since the magnetomotive pull is proportional to the rotation speed of the magnet, output pressure is also proportional to this speed. The zero spring is adjusted to produce the desired output pressure at zero rotation. The relation of the ball feedback unit to the disc axis is determined by a fine-range adjustment screw. Greater changes in range may be made by a series of fixed ratio drives between the input shaft and the integral speed changer input shaft.

practical and functionally superior is the method of measuring the moment created in a plate when it cuts lines of flux in a rotating magnetic field. Advantages of this method in an instrument are:

- The relationship of the moment created by the magnet to speed of rotation of the magnet (and its flux) is linear.
- It is easy to measure a moment mechanically with accuracy and to convert this to a linear pneumatic signal.
- The concept lends itself to a so-called force-balance design which is compatible with small size, minimum friction, and ruggedness.
- There is no explosion hazard as with tachometer-generator designs.

PNEUMATIC DESIGN

The simplicity of the linear relationship between the moment created by the magnet (and its flux) on the disc and the speed of rotation of the magnet made this method attractive. The design so far outlined would be only a magnetic tachometer. Transmitting ability for recording and control was necessary to make the equipment useful in industry and to help minimize the price advantage of purely indicating tachometers.

"In order to gain the advantages of pneumatic transmission and control," said a Foxboro engineer, "we designed a pneumatic instrument as an integral part of conventional pneumatic systems for centralized control. This eliminated the disadvantages of measuring electrically, such as the need for explosion-proofing and for conversion of electric signals to operate pneumatically-actuated control devices. Also, gasketed construction and continuous air bleed overcame the problem of corrosive atmospheres."

TORQUE VS. RESISTANCE

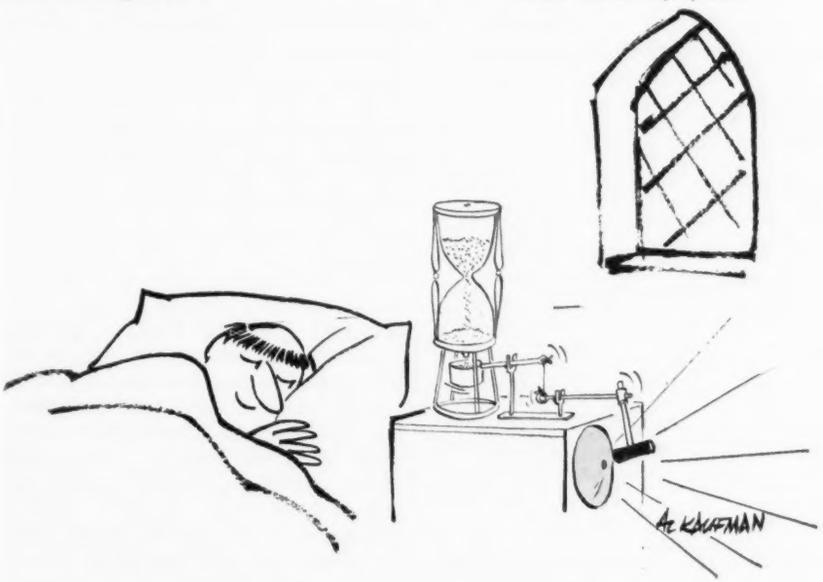
In carrying out the force-balance approach Foxboro engineers were confronted with an interesting problem. The disc on which the rotating magnet acts could be made of either a low or a high-resistance material. Low resistance would mean high torque but would also involve considerable current flow, which would cause the disc to heat, changing the resistance of the disc and so the torque. Low-resistance materials invariably have high-temperature coefficients of resistance. On the other hand a high-resistance material such as constantan alloy would remain at a fixed resistance; there would be effectively no heat problem. However, torque would be too low for effective operation.

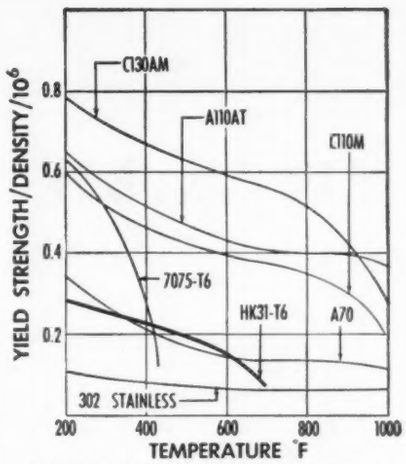
They decided to compromise between low and high. A fairly high-resistance, low-temperature coefficient material was used. The resistance was such that a reasonable torque was developed, while eddy current heating effect was negligible. To combat the effect of ambient-temperature-change on disc resistance, the designers used a bi-metallic shaft to alter spacing between magnet and disc, varying field strength in the disc to compensate exactly for its small resistance change.

Basically, this design problem was one of selecting known physical phenomena to suit certain requirements and adapting them for the proper solution.

Production units of the speed transmitter give ambient-temperature compensated accuracy of plus or minus one-half percent, immediate response of a fraction of a second, and flexibility of application from zero to 5300 rpm clockwise, counterclockwise, or both. The output is 3-15 psig pressure linearly proportional to rotational speed.

Circle 103 on Inquiry Card





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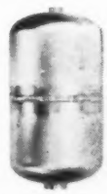

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Magnesium turret enclosure for a bomber. Design, lofting, prototypes, production fabrication and assembly are all done by B&P.

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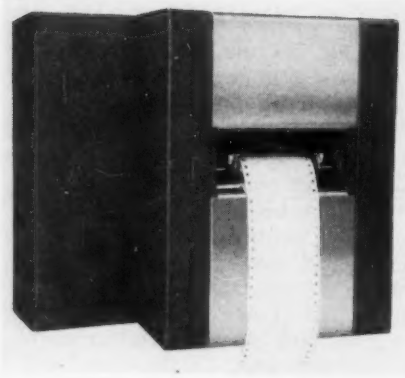

Alphanumeric Digital Printer

A new, very high speed, alphanumeric, digital printer designated Model 3260, has completely transistorized circuit modules housed in a compact package with the print mechanism and is suitable for desk or rack mounting. It can print more than 400 digits or characters per second and may be connected to most data producing sources with little modification. Associated equipment to make the printer applicable to any printing requirement may be supplied. The printer can be supplied with up to 40 columns of numeric or alphanumeric characters and is capable of printing at speeds of 20 lines per second for alphanumerical applications. Printing is normally done on multiple copy fanfold paper. A minimum of moving parts, elimination of mechanical linkages, and use of stellite type faces assure maximum reliability in the printing mechanisms. A selection of up to 63 characters are available including alphabetical, numerical, and special symbols in any desired combination. Standard teletype characters can be furnished. *Potter Instrument Co., Plainview, New York.*

Circle No. 202 on Inquiry Card

WORTH FILING

Health Physics

New pamphlet discusses all phases of health physics from personnel protection in the case of an individual engaged in nuclear research work to the protection of entire communities in the case of installation of nuclear power reactors. Includes such topics as individual protection via training for handling of radio-active materials and utilization of film badges, dosimeters, etc., to consultation, site evaluation and instrumentation in the case of nuclear power reactors.

Source: Tracerlab Inc.
Waltham, Mass.

For your copy: Circle No 163 on Inquiry Card

New Material for Water Resistant Seals

Superior water resistant qualities of a new synthetic rubber compound may prove to be a boon to manufacturers of home appliances and related equipment. The new material was formulated by the Parker Rubber Research & Development Laboratory, under direction of E. L. Carlotta, in response to the challenge presented by premature failure of seals, diaphragms and other synthetic rubber parts in domestic laundry machines. The failures usually allow water and soap or detergent solutions to migrate into vital mechanisms creating substantial repair bills, warranty claims and ill will on the part of users.

The swelling and deterioration of many synthetic rubber parts to the point of failure can be traced to long term exposure to water and laundry chemicals. Swelling action of long term immersion in water often has not been fully appreciated because many rubber specifications are based on an exposure test of only 72 hours at some standardized temperature. A more accurate appraisal of compound stability can be made if the exposure time more nearly represents machine life.

This reasoning induced the Parker laboratory staff to undertake development of the new material, designated Parker compound number 37-021, which has been verified to be exceptionally water stable throughout the comparatively long exposure test of 1440 hours. Throughout this aging period, there is little or no change in volume or hardness.

Other compounds, considered to be water stable on the basis of 72-hour tests, have been found to show extremely high swell in the 1440-hour test. Some compounds are made with a surplus of extractable plasticizer which washes out of the stock in service, and is merely replaced by water. This leaves the impression that the material has low volume change. Many times, however, if a dry-out condition is experienced, a severe shrinkage occurs and further deterioration follows. The new Parker material was concocted to maintain low volume swell and to avoid the equally serious problem of shrinkage.

The new material also has basic oil resistance, making it suitable for agitator shaft seals and back-up gaskets. Other applications where material of this type is expected to be of benefit include pump seals and impellers, liquid level switch diaphragms, water valve seals, oil slinger rings, dish washer and disposal seals, water conditioner seals, and so forth. *Parker-Hannifin Corporation, Cleveland, Ohio.*

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STAFF COLUMNIST

Ronald C. Vickery

Ronald C. Vickery is Head of Horizons Incorporated's Chemistry Department.

THE CHEMISTRY OF COMPONENTS

THERMIONIC EMISSION

The term "electron emission" covers every aspect of chemical physics from arc excitation to fluorescence and phosphorescence. Many of these have been widely covered in prior literature, and the use of rare earths as phosphor activators and in luminescent oxides is well known, although much of the underlying theory is less well established. Here we are basically concerned with the potential use of rare-earth compounds as thermionic emitters.

The value of lanthanum and cerium borides has been established in this regard, but little accurate data exist on the work functions, electronic affinities, not only of these compounds but of others of the rare earths. Predicting their properties in this respect is difficult because of their somewhat complicated electronic structure and valence composition. In lanthanum and cerium borides the rare-earth portion is ionically volatile, the boron matrix remaining unaffected until the rare-earth ion is substantially eliminated, after which the boride structure collapses.

In the general field of the rare earths it appears that, by virtue of the relatively low ionization potentials of the tervalent and bivalent rare-earth ions, appreciable activity may be found below the melting points of the respective metals (*ca.* 800-1200 degrees C), particularly so when they are either in a very pure state or retained within a very resistant lattice, such as tungsten, from which they could function as in the borides. Rare-earth tungstites, for example, might be expected to be of cubic habit; the combination of the two metallic lattices could well provide very low work functions and electronic affinity. In such a system heavier rare earths might be more effective emitters than lanthanum or cerium, even though the respective ionization potentials increase sequentially, since by this increase values approach those of tungsten, molybdenum, thorium, and rhenium; such close approximation of ionization potentials might well permit the exhibition of synergistic effects.

Rare-earth oxides, as has been indicated, are known to be currently under investigation by several workers in the thermionic field, but insufficient attention is being given to absolute purity of the oxides studied. Addition of microscopic or atomic impurities does, in some instances, increase emission by impurity migration effects, producing lattice defects of both Schottky and Frenkel types, but, in the studies now in progress, so many impurities appear to be present in the materials studied that it is difficult to determine emission due to the rare earths and that due to impurities. There would appear, therefore, a salient requirement for study on highly purified rare-earth oxides—not excluding other compounds.

Some preselection of appropriate rare earths might be founded upon the stability of their electronic structure. Essentially tervalent, valence electrons in the rare earths reside in the 5d and 6s shells; however, there is a serial increase in population of the 4f shell from $4f_0$ at lanthanum to $4f_{14}$ at lutetium. Zero, seven, and fourteen electrons in this lower orbit appear to be stable configurations, so that there is a tendency for electrons to migrate between the 4f and 5d or 6s shells in attempts to attain the stable configurations. This migration means that cerium, praseodymium, samarium, eropium, terbium, and ytterbium possess electrons which may, in a loose sense ,be termed "free," and thus these elements may be potentially stronger emitters than the majority of the other tervalent rare earths. Again, praseodymium and ytterbium from nonstoichiometric oxides, Pr_6O_{11} and Tb_4O_7, so that it may be expected that thermal excitation of such defect oxides would show enhanced emission, since electrons are more readily traversed with defect structures existing in such oxides.

We have indicated that there might be several rare-earth compounds which might display enhanced emission characteristics. Based upon the lanthanum boride concept, we have suggested the lanthanon tungstites; but the silicides or phosphides might be as effective. Rare-earth carbides are very active towards water and hydrocarbon vapors and may thus be excluded from consideration. The nitrides are somewhat unreactive, as are the hydrides, but the breakdown of such lattices would liberate compensatory nitrogen or hydrogen atoms.

Piezoelectricity

By the very nature of piezoelectric phenomenon, only crystals of unsymmetric habit can exhibit the piezoelectric characteristic. Several qualifying statements can be, and have been, added to ths generalization, but the fact still remains that piezoelectric characteristics are exhibited only by crystals lacking a center of symmetry, except those belonging to crystal Class 432—Schoenflies' classification O, cubic pentagonal icositetrahedral.

Thus piezoelectric studies can be concentrated immediately, but this fact does not suggest that only known compounds falling into unsymmetric crystal classes be considered. Close investigation must be given to any compound that might fall into the crystal groups indicated, taking advantage of the current increase in interest and studies on the chemistry of complex inorganic molecules.

Piezoelectric moduli of many crystals can be calculated, but in spite of adherence to any crystal form any one crystal may have characters which deviate from normal. Such deviations are inherent in most inorganic crystals and are basically determined by purity, hydration, etc.

Some crystalline rare-earth compounds have been examined for piezoelectric properties. Significantly, those showing strong k values are crystals of complex molecules in which a certain degree of coordination exists.

Coordination chemistry of rare-earth compounds has been closely studied in recent years, and bonding forces inherent in the structure of complex molecules built around the rare earths are profoundly appreciated. Currently, probably the most important of these rare-earth compounds are those with ethylenediaminetetraacetic acid and other aliphatic polycarboxylic amino acids (nitrilotriacetic, hydrazinediacetic, and iminodiacetic). Rare-earth complexes wth the first of these acids have already been found to exhibit piezoelectric properties of the same order as Rochelle salt.

However, not only hydrated, organic complexes of the rare earths are of value as piezoelectrics. Recently reported studies on the yttrium garnets indicate a much wider potentiality.

END

SERVO CONTROL

Direct Drive Eliminates Backlash In High Performance Servos

David C. Smith, Detroit Controls Division of American Standards, Military Products Department.

Requirements for rotary positioning of high-inertia mechanical loads to unusually high resolution have led to a unique method of servo control.

Generally, acceleration and speed requirements for a particular load are met by selection of a motor with gearing to drive the system. Selection of components may be such that the system transfer function is determined primarily by the motor itself and the gears of the first mesh, neglecting load compliance. Load inertia and friction may be reflected as negligible quantities to the motor shaft, and the motor itself may be the primary factor in determining system frequency characteristics.

However, when servo resolution of a very high order is a primary requirement and the determining factor in the performance of a system, a completely different concept for selection of the output power element is required. In this case the gearing, especially that necessary for transmitting several foot-pounds of torque, introduces backlash many times higher than that tolerable for the resolution required and makes stable operation with sufficient gain and bandwidth impossible. The most obvious way to circumvent this difficulty is to drive the load by coupling it directly to the control-motor rotor.

In application of this concept to stabilization of a controlled member with respect to inertial space, such as in establishing a stable platform or reference line in navigational equipment, another very important advantage results: the self-stabilizing nature of the load itself.

STABILIZED PLATFORM CONTROL

Direct Drive. Consider the case of a single-axis stabilized platform driven by a direct-drive torque motor, where the base of the structure is subject to all random motions of the vehicle to which it is attached. To stabilize the controlled member, it is necessary only to keep it stationary with respect to inertial space—a function it tends to accomplish by the nature of its own inertia. The only disturbing forces are velocity-dependent, introduced by means of motor damping and bearing friction between the base and motor rotor; these factors appear as mathematically similar terms in the equation describing the disturbing torque:

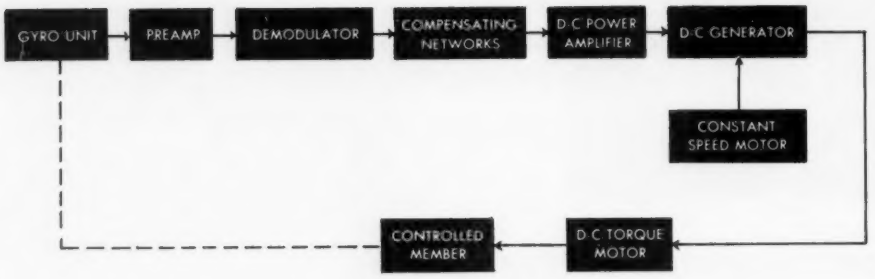

FIG. 1—Single axis inertial space stabilization system using a direct-drive torque motor to position the controlled member.

$$T = (f + K_n)\, d\theta/dt \qquad (1)$$

where

f = bearing friction
K_n = motor damping.

Perfect stabilization may be accomplished by overcoming this velocity-dependent torque.

Gear Drive. In contrast, consider a similar system of stabilizing a controlled member with respect to inertial space but with the driving force transferred by means of a gear train.

In this case, the output tends to be self-stabilizing in the presence of base motion also, but in contrast to the direct drive system, the servo motor rotates with respect to the base at a rate n times that of the load. Now, the disturbing forces coupled to the load, or controlled member, are attributable to bearing friction, motor damping at n times the rate cited in the direct-drive case and motor and gear train inertia which must be accelerated to maintain the controlled member stable. Thus, the disturbing torque is

$$T = J_{(m+G)}\, n^2\, (d^2\theta/dt^2) + [f_L + (f_G + K_n)n^2]\, (d\theta/dt) \qquad (2)$$

$J_{(m+G)}$ = Inertia of motor plus gears, referred to the motor
f_L = friction of the load bearings
f_G = friction of the gear train, referred to the motor
K_n = motor damping.

Comparison of the expressions representing the disturbing torques on the controlled member reveals that the effect of base-motion acceleration is entirely eliminated in the direct-drive scheme, and only velocity dependent terms are present, whereas in the gear-train method there is an acceleration term. In addition, motor damping and gear friction increased n^2 times are reflected at the output shaft.

DIRECT DRIVE CHARACTERISTICS

Figure 1 is a functional schematic of a single axis inertial-space stabilization system, stabilized by means of a single-axis integrating gyro unit. Assume that the controlled member inertia is fairly large. This system is required not only to provide sufficient torque to overcome friction tending to couple the controlled member to base motions, but also to allow initial position acquisition and restoration from disturbing torques. Typically, a d-c torque motor (a d-c motor of conventional configuration but specifically designed for this application) is used to provide driving torques up to several hundred foot-pounds. The generator, controlled by a push-pull d-c electronic power am-

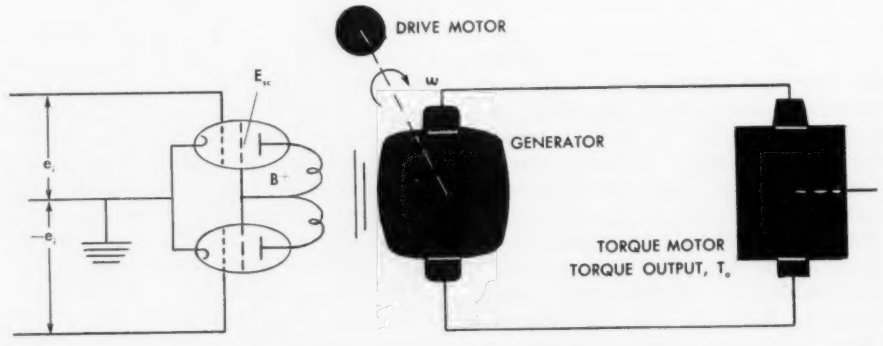

FIG. 2—Simplified schematic of servo-amplifier-output stage

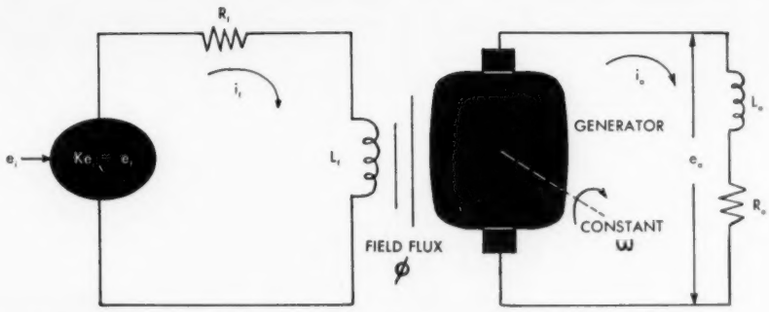

FIG 3—Functional diagram of servo amplifier output-stage.

plifier driving a specially-wound split-field, furnishes the high power and current amplification necessary to generate these torques. The preamplifier provides the necessary servo-loop gain and the signal after demodulation may easily be modified in phase and amplitude characteristics as required.

It is interesting to compare the transfer function of the power-and-driving member of this system with that which may be expected from a gear-drive system for accomplishing the same purpose. The entire output stage of the servoamplifier consists of the d-c power amplifier, d-c generator and the torque motor (Fig. 2). Interaction of the components prevents properly considering them as separate units, as the development of its transfer function will show. Figure 3 is a functional diagram of the servoamplifier stage where K is the electronic power amplifier gain.

The Laplace transformed equations describing the system are:

$$i_f = \frac{e_f}{R_f + L_f s} \tag{3}$$

$$\phi = K_f i_f - K_a i_a \tag{4}$$

$$e_a = K_\phi \phi \tag{5}$$

$$i_a = \frac{e_a}{R_a + L_a s} \tag{6}$$

where

s = the Laplace operator

K_f = the proportionality constant determining the portion of ϕ attributable to i_f

K_a = the proportionality constant determining the portion of ϕ attributable to i_a.

Normally a d-c generator is designed for positioning the brushes in a mechanically "neutral" position, so that there is no relationship between armature current and average field flux. However, if the brushes are shifted to a leading position, armature current degeneration occurs as described in Equation (4), the coefficient K_a being dependent upon brush position, which may be varied to a limited degree dependent upon proper generator commutation. The advantage of this action will be illustrated.

Solving Equations (3) through (6) for i_a/e_f, we obtain

$$i_a/e_f = K'/[(\tau_f s + 1)(\tau_a' s + 1)] \tag{7}$$

where

$$K' = K_f K\phi/[(R_a + K_a K\phi) R_f]$$

$$\tau_f = L_f/R_f$$

$$\tau_a' = L_a/(R_a + K_a K\phi)$$

Thus, K′ is the transconductance of the output stage, relating input voltage to torque producing output current.

The frequency dependent portion represents a second order system, τ_f being the time constant determined by the parameters of the generator field. Impedance of the field signal source may be varied to advantage, if necessary, in controlling the value of this time constant. τ_a' is the time constant associated with the generator armature circuit.

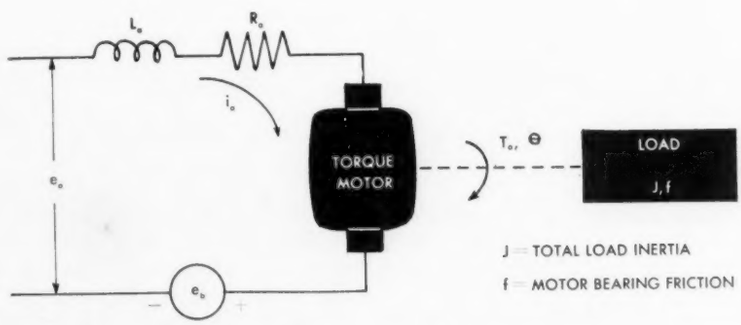

FIG. 4—Generation of output torque in direct drive d-c torque motor.

Control of the coefficient K_a has been explained. The result of the control is seen in the expression for both τ_a' and K′. While increased bandwidth (decreased τ_a') results from incrasing K_a, K′ is decreased as the normal inverse gain-bandwidth relationship is upheld. Variation in K_a is current feedback of i_a on the field flux.

The important point to note is that this control over the time constants τ_a and τ_f with any motor-generator torque motor combination selected to give the required power and torque output allows a reasonable system flexibility in meeting bandwidth requirements. Both of the time constants may often be made to give negligible effect in the region where system phase margin is critical. To extend the transfer function to include the entire system from the power stage to the output member, as expressed by θ/e_f, additional information is needed, as indicated in Equations (8) through (10) and illustrated in Fig. 4.

$T_o = K_T i_a$, the torque developed by the motor (8)

$T_o = (Js^2 + fs)\theta$, the torque absorbed by the load (9)

$e_b = K_v s\theta$ = Back emf (10)

$$I_a = \frac{e_a - e_b}{L_a s + R_a} \tag{11}$$

From the combination of these equations,

$$\frac{\theta}{e_f} = \frac{K_v}{s(\tau_1 s+1)(\tau_2^2 s^2 + 2\zeta\tau_2 s + 1)}$$

Here, $\tau_1 = \tau_f = (L_f/R_f)$ as before, τ_2 and ζ are associated with both the mechanical and electrical parameters of the armature, ζ being the damping coefficient and τ_2 the time constant. K_v is the system velocity constant; specifically,

$$\tau_2 = \left(\frac{L_a J}{f(R_a + K_a K_\phi) + K_T K_e}\right)^{\frac{1}{2}}$$

$$\zeta = \frac{J(R_a + K_a K_\phi) + L_a f}{2\left[L_a J[f(R_a + K_a K_\phi) + K_T K_e)\right]^{\frac{1}{2}}}$$

$$K_v = \frac{K_T K_\phi K_f}{R_f[f(R_a + K_a K_\phi) + K_T K_e]} \tag{12}$$

Again τ_2 becomes somewhat flexible through the variation of K_a, decreasing with the increase of armature current feedback. K_v shows the same variation as did K′ in Equation (7).

In the case where K_v, the back emf coefficient, is negligible the expression yields:

$$\frac{\theta}{e_f} = K_v \frac{1}{s(T_f s+1)(T_a' s+1)(sJ/f+1)} \tag{31}$$

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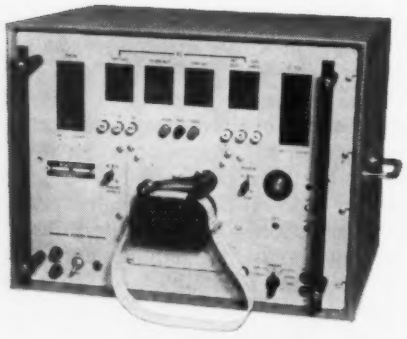

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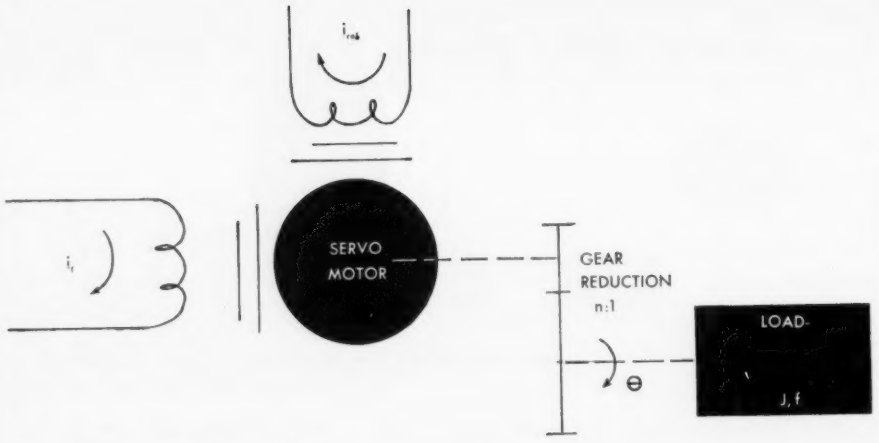

FIG. 5—Servo motor drive with gear coupling to load.

From the appearance of the transfer functions, Equations (12) and (13), the importance of the so-called "compensation" networks shown in the block diagram become apparent. Typically, in systems of this sort, the term J/f is extremely large and at very low frequencies the uncompensated characteristic equation shows 180 degrees phase lag. Therefore, even with τ_a' and τ_f designed to be quite low in view of over-all system requirements, "lead" compensation—or compensation that gives a positive phase characteristic in the region where system gain is about unity—is required. It should be noted that a single-order lead alone may not be sufficient to meet system requirements.

GEAR DRIVE CHARACTERISTICS

Disadvantages of geared drives in meeting the same requirements as direct drives have been mentioned. The transfer function that must be treated in such a system has not been indicated however.

In a geared electromechanical drive, torque gain is derived through the gearing and the motor-generator amplification used in the direct drive system is not necessary. Thus, the transfer function for the simple geared drive shown in Fig. 5 is

$$\frac{\theta}{i_f} = \frac{K_v}{s\,(\tau m s+1)} \qquad (14)$$

$$K_v = \frac{K_i}{n(f+Kn)}\,,\quad T_m = \frac{J}{f+K_n}$$

where,

f = output friction, referred to the motor shaft
K_n = motor damping
K_i = motor torque per unit input current
J = system inertia, referred to the motor shaft.

This function admittedly is easier to handle than the one described for the direct drive system, but there is a factor that should be included but which is not describable in linear terms. This, of course, is the effect of bearing backlash which, by any means of description, is still somewhat indeterminate. It results in a much larger system effective phase shift than Equation (14) predicts, usually resulting in the use of frequency response compensation even if T_m may be chosen to appear reasonably small for its application.

We have emphasized the use of a direct drive servo system to control a high inertia output member. However, the application of direct drive torque motors, in high precision instrument drives, should not be overlooked. This design technique may, in many cases, offer the best means available of meeting high resolution specification with a desirable bandwidth.

DIRECT DRIVE PERFORMANCE

The block diagram of Fig. 1 describes a system built by Detroit Controls Division of American Standard, Military Products Department. The output member whose inertia, J, was 25 ft-lb-sec^2, was controlled by an Inland Motor Corp. 8.0 torque motor, excited from a matched motor-generator set. In illustration of the success of the methods described, the following results were obtained:

System bandwidth:
18 cycles per second
Resolution:
±2 seconds of arc
Stiffness:
2 ft-lb/second of arc
Max. output torque: 14 ft-lb

The availability of direct-drive torque motors in both a-c and d-c models and ratings from a fraction of a foot-pound to several hundred foot-pounds allows the designer to apply this servo technique to practically any system that can benefit from its advantages.

MODULAR MAGNETIC STORAGE

For less than the price of a good oscilloscope, a project engineer can now have his own magnetic storage drum for testing, circuit development or research investigations. A new modular drum has been developed for use when an inexpensive versatile memory system is needed. It differs from a conventional magnetic drum design in that various size rims can be affixed to a standard hub thereby reducing production costs and providing more versatility. Motor, mounting, drive, and hub are standardized, leaving selection of drum diameter, read/record head, track diversity and speed to the systems designer. Should the drum's surface be accidentially damaged, only the rim need be replaced. The packaged unit is mounted on a $\frac{3}{4}$" thick aluminum plate ready for installation in any standard 19 inch rack.

This new concept permits engineers to acquire digital storage techniques, design read/record amplifiers, develop associated circuitry, and "prove out" logic before investing in a higher priced drum whose characteristics may be determined by the results of these investigations. Further, it permits circuit development to continue independently from that of the system and prevents the delays so costly to research and development programs. *Monroe Calculating Machine Company, Electronics Division, Morris Plains, N.J.*

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Variable Reluctance Angle Transducer

A new transducer for FM/FM telemetering applications uses a new principle to obtain precise measurement of angular rotation. Rotation of a magnetic rotor varies the amount of ferro-magnetic material in a fixed air gap and, because of the shape of the rotor, a change in the magnetic reluctance varies the frequency of an oscillator in a linear manner.

The transducer has broad application wherever exact measurement of a small angular position change is required and high resistance to very severe shock and vibration is essential. Its uses include installation on rocket motor gimbals, aircraft and missile actuators and control surfaces. The gage is also suited for industrial use under severe environmental conditions.

The manufacturer claims: the Transducer has practically infinite resolution for small angular ranges without the use of gears or screw systems to obtain

adequate output sensitivity; continuous shaft rotation is possible without damage or change in calibration; good acceleration sensitivity is provided in all directions. *Ultradyne Inc., Albuquerque, New Mexico.*

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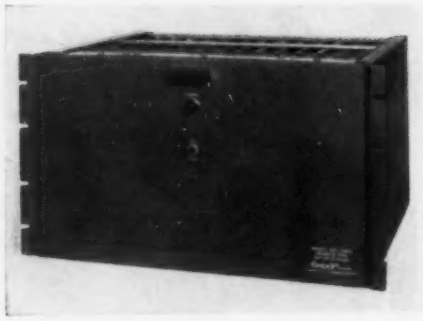

Versatile Memory for High-Speed Data

A new magnetic core buffer storage unit, designated Model CB-602/1000, with a total storage capacity of 1000 bits of information is said by its manufacturer to be an extremely versatile memory for the storage of high-speed (above 20KC) data. Since its construction is modular, assemblies of lesser storage capacity are also available.

The designers state that because of the unit's reliable magnetic storage elements (shift registers), power is consumed only during the times of read-in and read-out commands, and storage is retained indefinitely, even in the event of power failure. Shift registers may be connected in various combinations for special input and output capacities: up to 25 series words of 40 parallel bits; or 50 series words of 20 parallel bits. Further versatility of data output may be realized by the external connection of drive signals so that each shift register may be advanced independently, advanced in any combination with other registers, or advanced in groups simultaneously.

The unit is constructed for standard 19-inch rack mounting with power supply included. A hinged front panel permits easy access to components. *Epsco, Inc., Components Division, Boston, Mass.*

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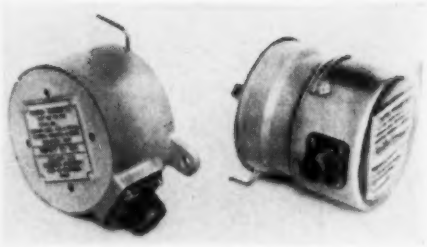


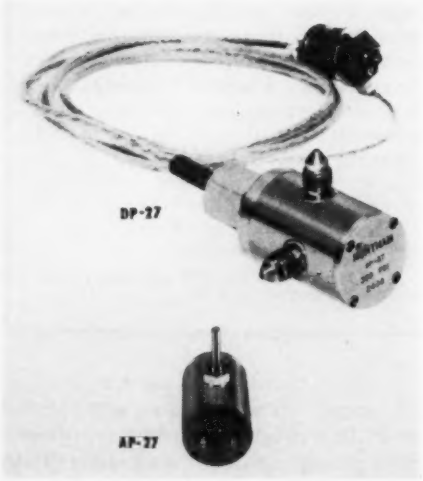
Special Precision Potentiometers

A unique pair of Precision Potentiometers actuate the hydraulic servo valve in the Nose Wheel Steering System of the new Convair Supersonic B-58 Bomber. The potentiometers consist of a nonlinear control transmitter using a 10:1 gearing system at the shaft input and generating a nonlinear steering curve having a slope ratio of 80:1, either side of center. The position transmitter uses three (3) parallel linear elements and supplies a feedback signal proportional to nose wheel position. Both of these potentiometers operate in a rather unique a-c bridge designed by Manning, Maxwell and Moore, and the necessary diodes, resistors and trimming resistors are contained within the potentiometer assemblies. In addition, the linear position transmitter contains a cam actuated limit switch which prevents the nose wheel from deflecting through an excessive angle. The potentiometers are packaged in rugged, environment-proof housings, and with a sensitive Manning, Maxwell and Moore valve are part of a remote positioning system which requires no electronic amplification. A series of detailed engineering bulletins covering special precision potentiometer applications is yours for the asking. *Technology Instrument Corp. of California, North Hollywood, California.*

Circle No. 197 on Inquiry Card

Variable Reluctance Pressure Transducers

Two new rugged, compact variable reluctance pressure transducers, Model DP-27 for differential pressure measurements and Model AP-27 for absolute pressure measurements, are said to have proven their reliability in severe missile and aircraft applications under conditions of mechanical shock, vibration and acceleration at which other transducers fail. Both models have Type-416 stainless steel construction for case and internal diaphragm which, the manufacturer says, results in homogeneity, low leakage, and minimum zero shift with temperature changes. All electrical components are imbedded in epoxy.



Pressure change is detected through two variable inductances by means of the variation in air gap in the two magnetic circuits as the pressure sensing diaphragm is deflected. Both instruments may be operated with a-c carrier systems ranging from 400 cps to 20,000 cps. Different ranges of coil inductance may be specified for compatibility with the desired carrier system. Since the transducer's frequency exceeds 2,500 cps, best results are obtained using the recently developed Northam carrier system operating at 3,000 cps.

The DP-27 is available in standard ranges of ±7.5, ±50, ±150, ±500, ±1500 psid but may also be specified in any desired range between ±7.5 and ±2000 psid. This transducer will withstand line pressures up to 2000 psi and over-range pressures of twice full scale. Hysteresis is 0.5 percent of full scale or less for ranges up to 100 psd and 1 percent or less for higher ranges, while linearity is ±1 percent of full scale or better. Over the temperature range from −65 degrees F to +250 degrees F, the zero shift is 0.02 percent F.S. per degree and sensitivity change is 0.04 percent F.S. per degree without compensation; with compensation, variations in both zero and sensitivity can be reduced to less than 0.01 percent F.S. per degree. Output of the DP-27 is ±40 mv per volt (compensated) and ±55 mv per volt (uncompensated). The transducer case is 1 inch O.D. and 1.5 inches long, and it weighs 5 ounces.

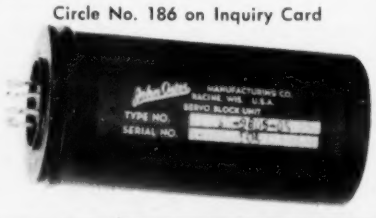
Standard ranges for the AP-27 are 0-15, 0-30, 0-100, 0-300 and 0-1000 psia, with other ranges available on order. The case is 0.997 inch O.D. and 1.46 inches long, and weighs 3 ounces. *Northam Electronics, Inc., Altadena, California.*

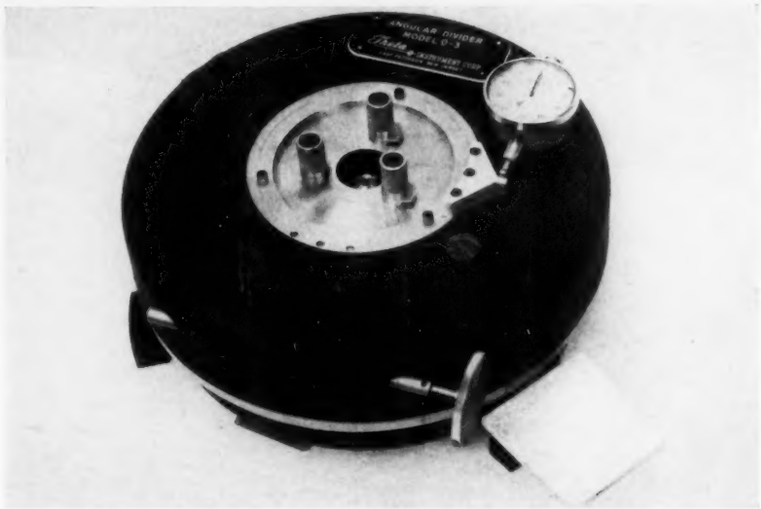
Circle No. 199 on Inquiry Card

Sealed Quadrature Rejection Unit

Hermetically sealed quadrature rejection unit instantly achieves 90 percent or more of full speed when turned on at −60°C to +80°C. When properly excited the output will be an ascending saw tooth voltage. Motor voltage is 26 V, 400 cycle, 2 phase. Type SB-9505-04 has motor input power of 3.2 watts max. per phase and potentiometer linearity of 1.5 percent max. Designed for precision servo systems applications. *John Oster Mfg. Co., Avionic Division, Racine, Wisconsin.*

Circle No. 186 on Inquiry Card





PRECISION ANGULAR DIVIDER, Model D-3, used for angular positioning of synchros without additional fixturing, has automatic colleting and direct readings permitting use by unskilled personnel. Shafts of rotating components are positioned to an accuracy of 20 sec of arc. Flexible couplings are avoided by using the synchro shaft to locate the center of rotation of the synchro housing.

A precise detent mechanism is used to position the synchro rotor. The large-angle divider is a 72-tooth, hardened-steel, ½ in thick plate with a spacing error less than 10 sec of arc between any two notches. A hardened-steel ball detent is mounted upon a cantilever spring which forces it into the notch. Due to the spring design, the ball has no play in a direction tangential to the plate. While the plate is being rotated about its center, a lever retains the detent from the notch. At the approximate angle, as shown by an engraved dial, the detent is released. The plate is torqued to the exact angular position by the detent force. To span the angular interval between the five degree notches on the plate, the fine-angle mechanism is used to position the synchro housing.

Adaptation to all housing and shaft sizes takes one minute at a cost of $100 per adapter. Specs include positional error, 20 sec max; weight, 30 pounds; diameter 12 in; height 5¾ in. Theta Instrument Corp. East Paterson, N.J.

Circle 101 on Inquiry Card

PRESSURE TRANSDUCER

RELUCTANCE TYPE PRESSURE TRANSDUCER features high d-c output plus practically infinite resolution, high-frequency response and ruggedness to shock and vibration. The P-900 is small, light-weight, accurate and especially suited for airborne, test stand and laboratory applications such as TOE-type voltage controlled telemetry, air-data and guidance systems, and direct d-c data recording. Many applications previously handled exclusively by d-c instruments such as potentiometer and strain-gage type transducers may now be served by this instrument. Datran Electronics, Manhattan Beach, Calif.

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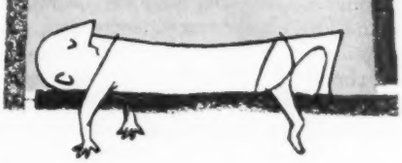

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CIRCLE 16 ON INQUIRY CARD

ANNUNCIATOR SYSTEM

No Moving Parts: Magnetic Elements Replace Relays

An annunciator system with no moving parts for utility generating stations will get its first application when the Public Service Electric and Gas Company of New Jersey employs it to monitor 560 critical quantities in their new 580-mw Bergen station. Developed by Westinghouse Electric Corporation, the system uses modular plug-in magnetic elements rather than relays. In over-all design it will be similar to Cypak static control systems for industrial control applications, but circuit components are different. Static annunciator systems house several information processing components in a single plug-in module; standard Cypak industrial control systems require several modules.

Advantages of the new annunciator system center on the extreme long life and reliability of magnetic elements, but its designers list others of significance. They include better testing—pressing a single button puts all of the logic elements in an 80-point system through a complete cycle, including the lamps, bell and buzzer; low-power requirements—1 watt per monitor point on standby, 80 watts when lamp is lit; and inherent "memory," which enables the equipment to resume proper indication after a power outage. Also included is electrical isolation of monitor

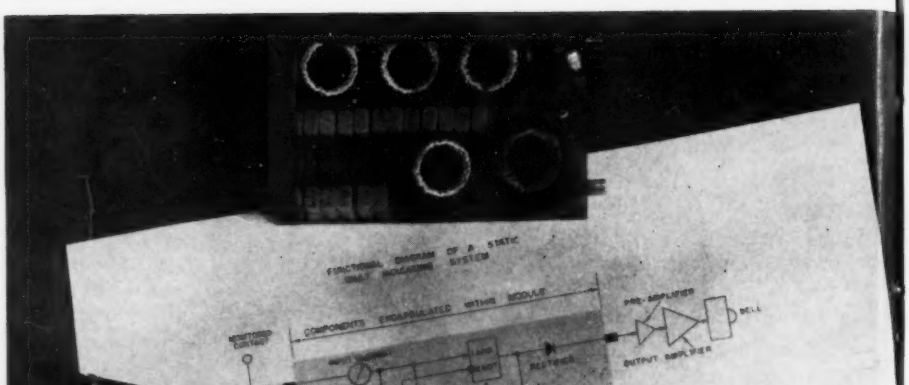

Fig. 1—By encapsulating information-handling components in a single module, designers of static annunciator systems achieve plug-in installation. Shaded area in the photograph comprises components for a single monitored point.

THE SEQUENCE OF OPERATION	Indicating Devices Bell	Light	Buzzer
No Fault	Off	Off	Off
Fault Condition Registered at Monitor Point	On	Flashing	Off
Fault Acknowledged by Operator	Off	Steady	Off
Fault Condition Corrected	Off	Flashing	On
Corrected Fault Acknowledged	Off	Off	Off

Fig. 3—Sequence of operation for annunciator system.

TITLE	SYMBOL	FUNCTION
PHASE INVERTER	Input 1 → Output	Gates an output when signal present at 1
THREE INPUT AMPLIFIER	Input 1, 2, 3 → Output	Gates an output when signals present at 1, 2 and 3
AND-NOT	Input 1, 2 → Output	Gates an output when signal present at 1 and not at 2
INHIBITED AND-NOT	Input 1, 2, 3 → Output	Gates an output when signal present at 1 and not at 2 or when signals present at 1, 2 and 3
OR	Input 1, 2 → Output	Produces an output when signal present at 1 or 2 or both
INITIAL INPUT ELEMENT	Input → Output	Steps down the level of input signal
RECTIFIER	Input → Output	Isolation

Fig. 2—Function of the logic elements in a static annunciator system.

signals, the ability to function over a voltage range of 75 to 140 volts, and the ability to convert the system for normally open or normally closed operation simply by installing a different control module.

As designed for Public Service Electric and Gas Company, the system brings five hundred and sixty 115-volt inputs to the relay room, where each of seven cabinets houses a separate 80-point alarm system. These are, in turn, arranged in 20-point subgroups; any subgroup can be removed from the system by a single switch.

Bells, buzzers, and lamps for the system will be installed in the control room, one floor above. Under a "ring-back" modification, an incoming alert signal initiates a visual indication—a flashing lamp—and drives a bell, as the first of two audio indicators. When the alert is acknowledged by the control room push button, the flashing lamp becomes steady and the bell is silenced. Whenever the cause for the alert is eliminated, the lamp begins to flash again and a buzzer sounds a second audio signal. Upon acknowledgement of the corrected condition, lamp, bell, and buzzer return to standby.

The basic system is designed to permit modifications desired by individual utilites. Among these are provisions for lock-in operation to signal occurrence of conditions as brief as two cycles; for lamps that glow continuously at low candle power to permit spotting burnouts; and operation without ring-back, with one audio signal only.

FUNCTIONAL DESIGN

Function of the logic elements in a static annunciator system, Fig. 2, gives the name, symbol, and the function of each element in one monitor circuit. Used with Figs. 1 and 3, it facilitates understanding the operation of the system.

With no fault signal, none of units A, B, C, D, or E (Fig. 1) are producing an output. Under normal conditions the "memory" units (B and C) are preset to produce no output. If unit B does not produce an output, C cannot have an output since it has no input. Therefore, unit B has no signal fed back to B-1 and has no output. Since no signal is present at A-1, D-1, or E-1, these units have no output; bell, buzzer, and lamp are not energized.

When a fault condition is registered, the bell rings and the light flashes. The fault causes the initial input element to send a signal to A-1, B-3, D-2, and E-3. The "memory" units (B and C) do not gate an output as no signal is present at B-1 and, consequently, at C-1. Unit A gates an output since a signal is present at A-1 and not at A-2.

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FOR MORE INFORMATION CIRCLE 18 ON INQUIRY CARD

This unit rings the bell. Unit D does not gate an output as no signal is present at D-1. Unit E gates a pulsating output which causes the light to flash. The reason is that E-1 and E-3 receive a steady signal and E-2 receives a pulsating signal from the static pulser.

When the fault is acknowledged (by momentarily closing the contacts of the "acknowledge" push button), the bell is turned off and the lamp glows steady. This is accomplished by the following circuit conditions:

- The "*memory*" units (B and C) gate an output when the acknowledge button is closed. Unit B gates an output as signals are present at B-1, B-2, and B-3; consequently, unit C gates an output as a signal is present at C-1.
- The "memory" units continue to gate outputs when the acknowledge switch is opened since a signal is present at B-1 but not at B-2. Hence, C gates an output.
- *Unit A* no longer gates an output because a signal is now present at A-2; accordingly the bell is silent.
- *Unit D* does not gate an output as a signal is present at D-2; accordingly the buzzer is silent.
- *Unit E* gates a steady output since steady signals are present at 1, 2 and 3; the lamp now burns steady.

When the fault condition is corrected, the buzzer sounds and the light flashes; this occurs since the "memory" units continue to gate an output (unit B has a signal at 1 but not at 2). Unit A does not gate an output, but unit D does. Since a signal is present at 1 but not at 2, unit D sounds the buzzer. Unit E gates a pulsating output that causes the lamp to flash; this occurs since a steady signal is present at E-1 and E-2 and a pulsating signal is impressed at E-3.

When the operator acknowledges that the fault is corrected, all outputs are now turned off. The "memory" units do not gate an output when the acknowledge button is depressed. Unit B does not gate an output as signals are present at B-1 and B-2; hence, unit C also does not gate an output. The "memory" units remain off when the acknowledge button is no longer depressed since a signal is not present at B-1. Unit A does not gate an output as no signal is present at A-1. Unit D does not gate an output as no signal is present at D-1. Unit E does not gate an output as no signal is present at E-1. The "alarm control center" is now ready to register the occurrence of a new fault and to be re-cycled through its sequence.

This entire sequence can be initiated by depressing the "test" push button. Closing these contacts duplicates all the operational consequences of an actual fault.

Circle No. 178 on Inquiry Card

PNEUMATIC-ELECTRIC PUMP CONTROL

Variable Speed Pulley Drives Regulate Pump Rates

In modern sewerage treatment plants, automatically controlled pumps lift the sewerage from a concrete-chambered wet well where it is collected to the equipment where it is processed. Dependable control of pumping rate is a major problem in treatment plant design.

A basic characteristic of the treatment process is a great difference between maximum and minimum flow of material to be processed. Level of material in the wet well is a measure of load on the plant. To use the processing facilities at fullest advantage, the pumps should operate at a capacity proportional to wet well level.

Numerous mechanical and electrical methods are being used to control pump speeds. A pneumatic electric system, described by E. R. Forman and W. R. Jensen of the Moore Products Company at the ASME Annual Meeting in New York, December 1-6, 1957, is claimed to be more flexible and dependable than previous systems.

This system installed at the new Penns Grove, N. J., Sewerage Authority Treatment Plant accomplishes switching and loading of the pumps by a pneumatic proportional control circuit coupled with electric motors. Pump rates are controlled through variable speed pulley drives rather than through variable motor speeds, thus allowing the motors to operate at peak efficiency. Design of the systems is described in the illustrations.

A major objection to conventional pumping systems which do not have proportional control is that they introduce bumps in the treatment process tending to lower its efficiency in removing solids from sewerage. Since state regulations are generally specific as to the efficiencies over which a plant is permitted to operate, good control is imperative.

Mr. Forman and Mr. Jensen list several advantages of the new system:

- The system offers completely automatic control, with optional manual operation for any of the pumps, at any time
- Any pump may be put "on stream" at any time
- In a proportional control system the wet well acts as a surge tank which evens out the flow to the rest of the

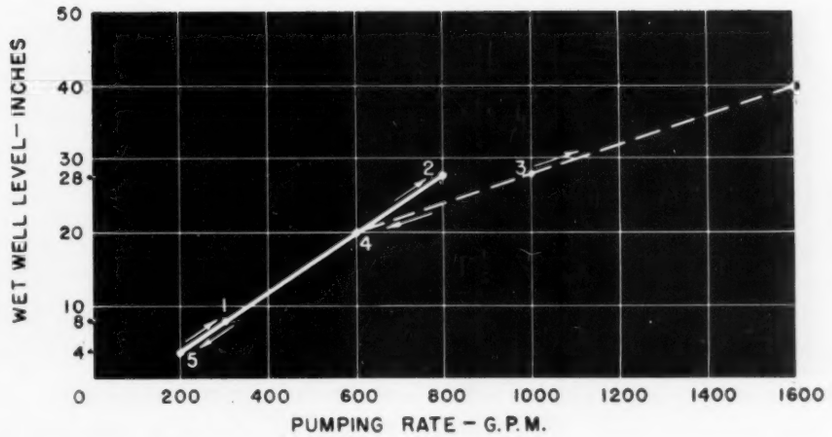


FIG. 1—Pump speed versus level of wet well. To prevent damage from their running dry, the pumps do not operate when the level is below 4 inches. The level must rise to point 1 before pump 1 starts at a rate of 300 gpm. If the level should fall because the pumping rate is higher than the input rate to the well, the speed gradually decreases with level until it cuts off at point 5. Pump 1 increases speed in proportion to increase in level until point 2, where it cuts out. Pump 2 cuts in at a rate of 1000 gpm at point 3. If the pumping rate is greater than the input to the well so that the level falls, the speed of pump 2 will also decrease, but there will be no switch-back to pump 1 until the level drops back to point 4. If the level rises above point 3 the capacity of pump 2 increases up to its maximum of 1600 gpm. A high alarm gives a warning at unsafe levels above the maximum pumping capacity. Under emergency conditions, pump 1 can be operated on manual, supplementing the automatic operation of pump 2.

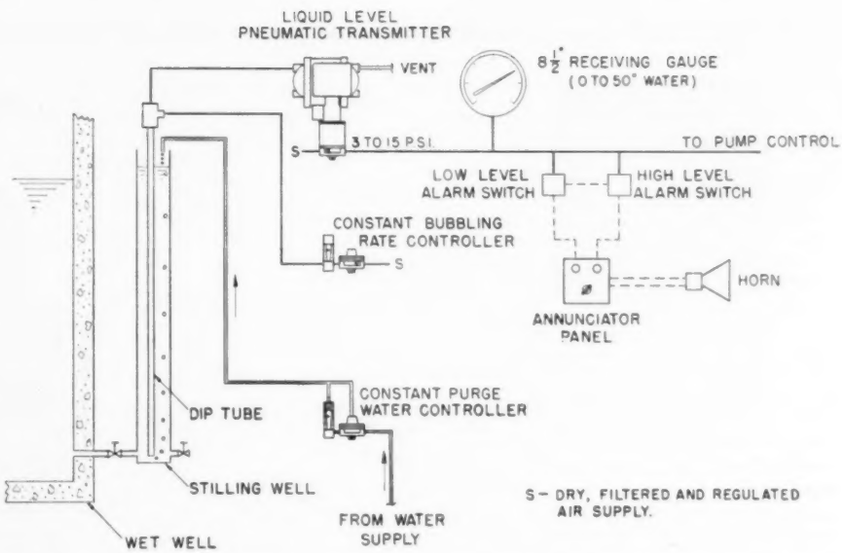


FIG. 2—Liquid-level measuring section. The liquid-level measuring system measures the liquid level and converts this quantity to a pneumatic signal for operation of the pump control circuit.

The stilling well provides a place where the dip tube may be operated without detecting small disturbances such as waves in the wet well. It also provides a constant purge of clean water to keep sewage particles from clogging the well and fouling the dip tube and reduces the number of shut-downs for cleaning. The small air-purge controller maintains a constant bubbling rate of air, regardless of the level depth. Increases in the level require higher air pressures to maintain the bubbling-rate constant. Since the air pressure is directly proportional to the liquid level, measurement of the air pressure is equivalent to measurement of liquid level.

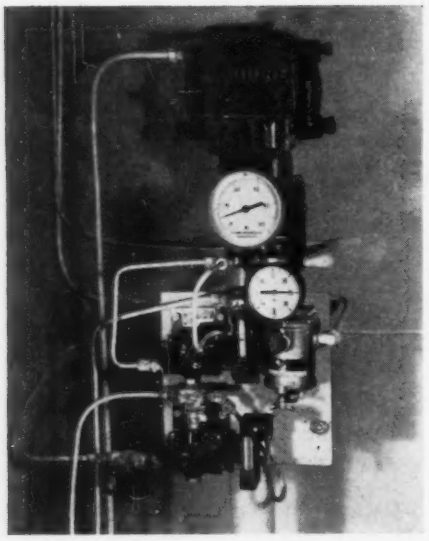


FIG. 3—Liquid-level transmitter with its water purge and bubbling air controllers. The liquid-level pneumatic transmitter changes the air pressure signals representing the liquid level over the range from 0 to 50 inches into proportion pneumatic signals ranging from 3 to 15 psig. These signals are the only ones required to operate the control system. The auxiliary equipment includes an indicating gage and a high-low alarm system. This equipment operates from the pneumatic signal. Settings for the alarm points can be made for any values within the operating range. Alarm lights and reset controls are mounted on the front of the operating panel.

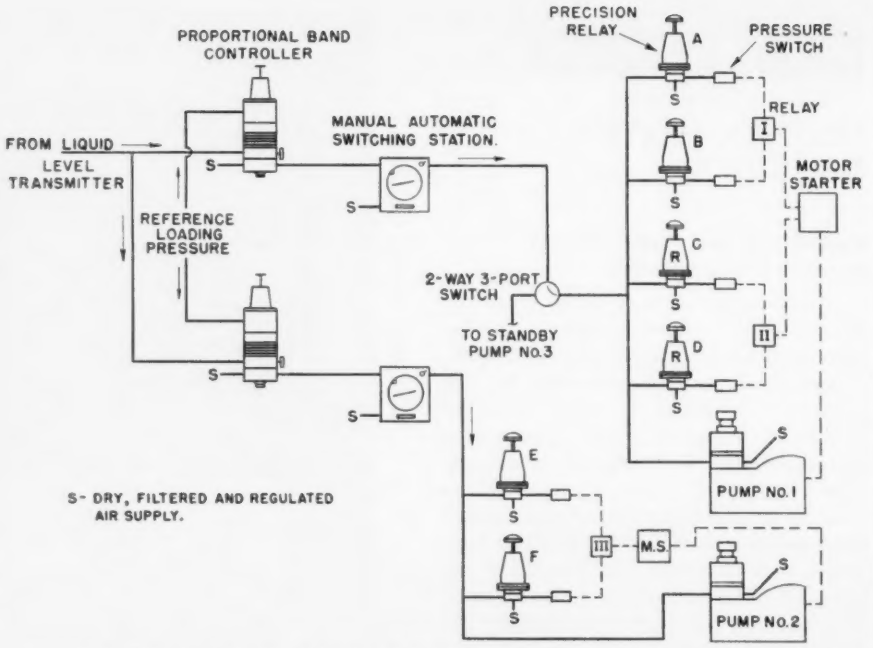


FIG. 4—Pump-control circuit. This circuit controls pumping rate and switches the motors. The pneumatic signals from the liquid-level transmitter are sent to the two proportional-band controllers which have self-contained set point adjustments and 2 to 200 percent proportional-band adjustments. Their function is to control the speed of pump 1 or 2 over its selected range in proportion to signal input. Adjustment of the set point and of the proportional band varies the span of input signals to which each pump responds over its full pumping range. This flexibility provides an infinite number of combinations. In this circuit, only relays C and D are reverse-acting units, used to provide the proper switching action for pump 1. The switches operate in pairs to actuate electrical relays I, II, and III. For example, as the level rises from zero, both precision relays A and B must actuate their electric pressure-switches to start the pump at the preset level. When the level is decreasing, both switches must drop out before the pump will stop. The stand-by circuit is a duplicate of pump 1 and its switches. This unit is operated alternately with pump 1, distributing wear on the most frequently operated units. This arrangement also allows for pump maintenance without disturbing the operation of the plant.

FIG. 6—Typical operating characteristics of stack-type controller showing the flexibility of its design. The pump will operate from its minimum to its maximum range, over a level change that can be narrowed or widened by changing the proportional-band setting. In the field, the operator need only select the set-point to determine the middle of the desired band and then adjust the proportional band by the knob on the controller until the end points meet his requirements. No involved calculations are necessary. In this installation, pump 1 is operating from a 4 to 28 inch level, or a total change of 24 inches. The set-point is at 16 inches (4 inch base, plus ½ of the 24 inch total band). The desired band of pump operation is 24 inches out of a 50 inch total level range.

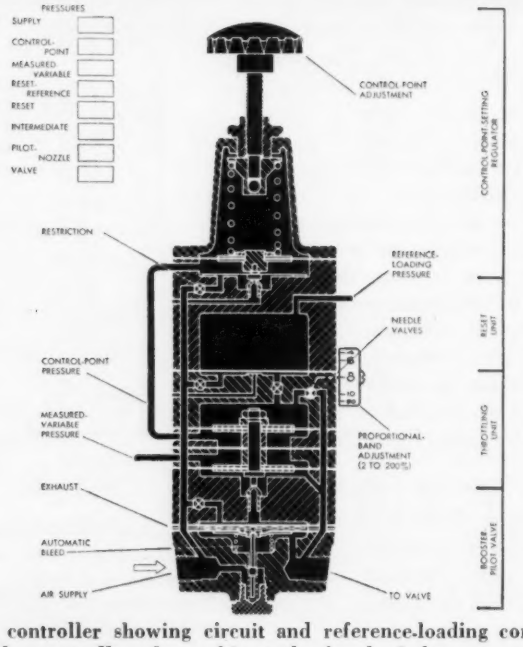


FIG. 5—Stack-type controller showing circuit and reference-loading connection. Making the set point of the controller always bisect the band of the pump operation is easy with this force-balance, stack-type controller using a 9 psig reference-loading pressure. Its force-balance characteristics eliminate friction-producing levers and pivot points. Consequently, even small level changes are detected by the controller, and a smooth change in pump speed results.

plant and results in more efficient operation and closer control of the treatment process

• The level-measuring device offers no explosion hazard. The pneumatic transmitter is completely isolated from the corrosive atmosphere in the wet well. No floats, cables, nor electrical contacts are used

• The pump and motor life is greatly lengthened, since starting and stopping occur infrequently. The system is specifically designed to avoid on-off operation

• In the system of operating the small pump for low flows and the large pump for high flows, each unit performs in the most efficient portion of its curve

• By controlling pumping rate rather than motor speed, the motors can be set to operate at maximum electrical efficiency

• The suction pressure is maximum at the highest pumping rate because the pumping rate is in proportion to the level in the wet well

• The load can be distributed on the pumps in any desired pattern.

Circle No. 151 on Inquiry Card.

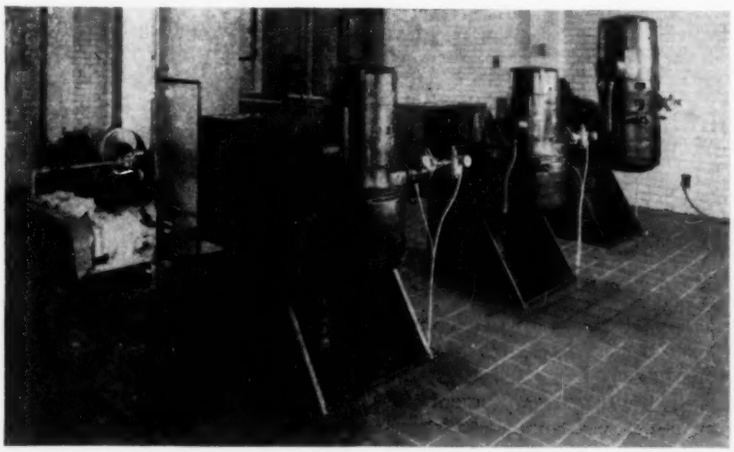
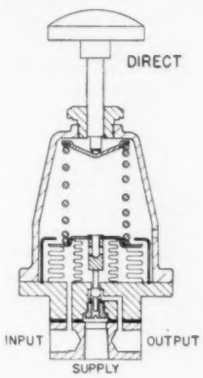


FIG. 7—Variable-speed pumps used on Penns Grove Installation. The pump-speed unit consists of a pneumatic cylinder, equipped with an integral valve positioner, which actuates a set of adjustable V-pulleys, changing the speed transmitted from a constant-speed motor. The unit is so designed that, with a 3 to 15 psig input, the pump will operate from minimum to maximum values in its usable pumping range.



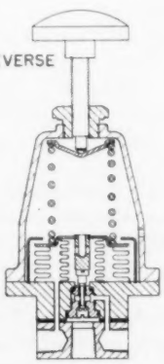


FIG. 8—Precision relays. The automatic switching portion of the system determines which pump operates at a given level. It also accomplishes the overlapping band of operation at the low level and the switch-over point from pump 1 to pump 2. The electric motor for each pump is a constant-speed unit turned off and on by the action of precision relays and pressure switches. The precision relays have adjustable "firing points." In the direct-acting unit, the supply line is normally blocked. When the controller-output pressure reaches or exceeds the set-point of the precision relay, the pilot of the relay admits full supply pressure to the pressure switch, which closes an electrical connection. In the reverse-acting unit, the supply pressure cuts off and the output line bleeds to the atmosphere when the set-point is reached or exceeded. There is a definite advantage in using the precision relay, rather than in using a conventional pressure-switch. The relay may be set to operate within approximately 1 percent of its range for any given set-point. This setting is made accurately and conveniently by turning the knob on top of the relay.

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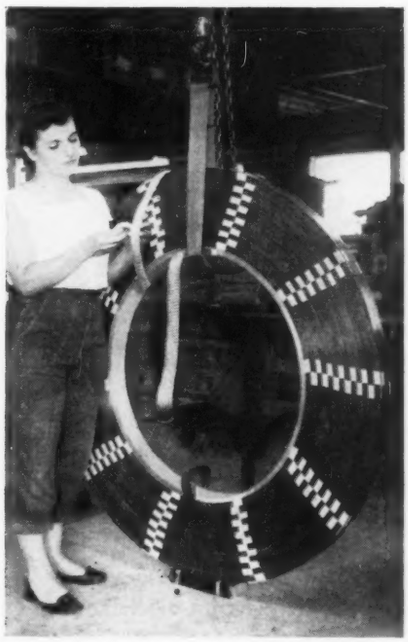

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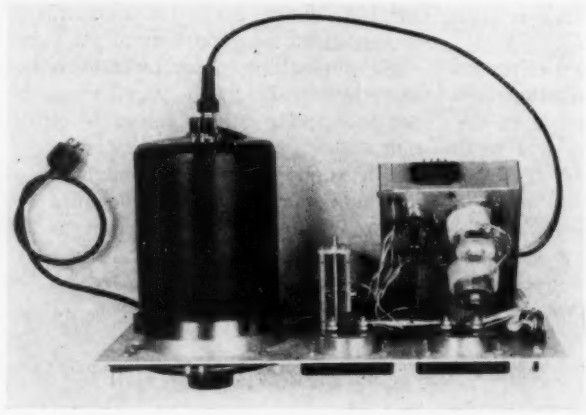


To the left is the radio frequency generator of the Ophthalmo-Electrotome. The chassis at the extreme right contains the r-f power output amplifier and the driver preamplifier. To the left of the chassis is the tuning capacitor. An important feature of this equipment is that the simplified tuning procedure enables the physician to prepare the instrument for operation in less than 10 seconds.

MEDICAL ENGINEERING

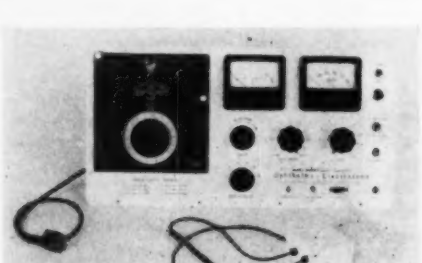
Improved Control for Electronic Scalpel

New York Hospital-Cornell Medical Center is conducting an experimental program to improve the effectiveness of electrosurgery. To aid this program Ford Instrument Company has designed and built test equipment for obtaining closer control of electrosurgical parameters. One such item is its Ophthalmo-Electrotome for performing the extremely delicate task of repairing detached eye retinas.

Electrosurgery is an operating technique using an electrical knife, which is basically an electrode connected to an electrical power supply. When power is turned on, the electrode issues a fine radio frequency current effective in cutting tissue.

First used about the turn of the century, electrosurgery has a hemostatic action which cauterizes the wound. Thus, an incision can be made without the usual accompanying blood streaming from the wound. Among other advantages it reduces the obscuring effects of blood from the area being operated upon. The extent of the hemostatic action is accomplished by changing the knife's electrical power output.

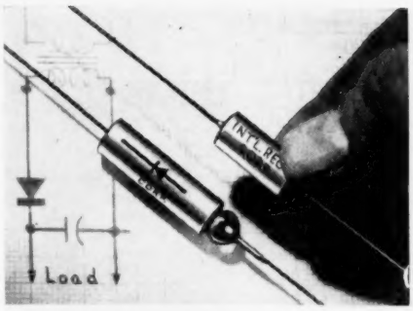
Design of most present-day electrosurgical equipment has changed little since the early machines. The high-frequency power generator in most units is a spark coil and gap. Drawbacks of this arrangement are instability of voltage, frequency and power, which vary according to the electrical characteristics of the tissue being operated upon. As a result, a surgeon needs practice with each particular instrument to develop the technique and judgment required. It's a case of the man adapting to the machine rather than adapting the machine to the man.



Control panel of Ford Instrument Company's Ophthalmo-Electrotome serves both to control and to measure the electrosurgical variables during the course of an operation. The frequency and voltage of output are controlled from this panel. The repetition rate of r-f output pulses or the wave form of output may be prescribed by inserting modulation into the appropriate jack. It also is possible to set automatically the length of time that radio frequency power is applied to the eye by adjusting the simple timing circuit controls. In addition, electrode voltage and current applied to the eye are registered on the panel meters. Connections are provided for recording these voltage and current quantities.

Instability of electrical output for electrosurgical equipment is not a major consideration when minor operations are performed. However, great care and control must be exercised when such delicate areas as the brain and eyes are involved.

Unlike conventional electrosurgical equipment, the Ford device enables the surgeon to control both voltage and frequency and thus prevent burning delicate tissues. This instrument is now being used on research animals at the New York Hospital-Cornell Medical Center. END



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A new series of high voltage silicon cartridge type rectifiers are applicable to radar power supplies, high voltage bias supplies and airborne or guided missile instrumentation.

This new series, rated at 100 ma. rectified d-c output current, comprises the IN1410, IN1412 and the IN1413, with peak inverse voltage ratings of 1500, 1800, 2000 and 2400 volts respectively. Hermetically sealed, cartridge type construction, offers space and weight savings, as well as improved mechanical stability over the vacuum tube rectifiers they replace. The operating temperature range for these diodes is -55°C to 150°C ambient, with optimum reliability at elevated and sub-zero temperatures. Addition of these rectifier types provides the design engineer with a complete range from 600 to 2400 volts PIV in this cartridge type diode series. Bulletin available. *International Rectifier Corp., El Segundo, Calif.*

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Self-Aligning Air Duct Joints

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WORTH FILING

New Process for Etching Printed Circuits

A new process for etching printed circuits with a solution of ammonium persulfate instead of ferric chloride is described in a new Becco Bulletin, No. 90. Advantages of the persulfate bath over ferric chloride include: the etchant is relatively non-corrosive; sludge formation is avoided; only water-soluble reaction products are formed; solder-plated circuits can be etched; copper can be recovered from the spent etching solution; waste solution can be disposed of easily. Preparation of the solution, processing instructions, after-treatment, and disposal of the waste solution are fully outlined.

Source: Becco Chemical Division
Food Machinery and Chemical Corp.
Buffalo, New York

For your copy: Circle No. 182 on Inquiry Card

Self-Calibrating Accelerometer

A self-calibrating accelerometer designed primarily for control and guidance in aircraft and missiles is also applicable in fire control, servo guidance and pitch and yaw correction characteristics. Designated the Glennite Differential Transformer Accelerometer, Model ADT-905, the unit is equipped with a self-contained calibration system which can be used to check the operation of the accelerometer while in use, or to calibrate the accelerometer statically or dynamically. The self-calibrating system incorporates a force generating device which applies a force to the seismic system in proportion to the electrical excitation applied. The unit is inherently stable over the entire temperature range of −76°F to +250°F because of its balanced electrical and mechanical construction. Operating at a low natural frequency of approximately 30 cps, the self-calibrating accelerometer maintains stable frequency response characteristics over the temperature range as a result of magnetic damping. Because of extremely high sensitivity the Model ADT-905 replaces potentiometer accelerometers and is easily adapted to phase-sensitive modulators. Input can be isolated from output as required in many systems. *Gulton Industries, Inc., Metuchen, N. J.*

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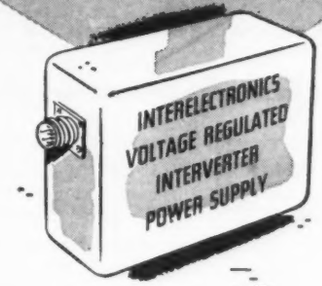

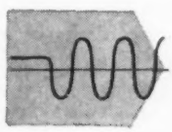

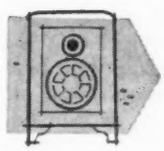

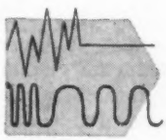

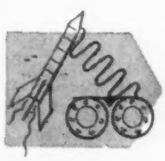

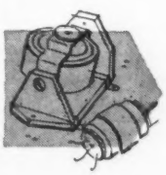

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STAFF COLUMNIST

Israel Katz

Israel Katz is manager of Liaison and Consulting Engineering at General Electric's Advanced Electronic Center in Ithaca, N. Y.

Part I of this column appeared in the Sept.-Oct. Issue, 1957. A limited number of free reprints are available; circle 100 on the reader-inquiry card.

THE HEART OF THE MATTER

The Combined Environment: A Challenge to Design Resourcefulness

A prime consideration in the design and development of electromechanical devices for military supersonic vehicles and, by all odds, the criterion for choice of all such electromechanical subsystems is the exhaustively-weighed contribution of each component and piece of equipment to a vehicle's effectiveness. *Successful accomplishment of mission is the decisive measure of that effectiveness.*

From the offensive viewpoint, effectiveness depends upon the weapon system's ability to detect and destroy targets. To do this the vehicle's offensive subsystem must perform on demand in the presence of physical hazards. From a defensive standpoint, survival against enemy measures depends upon the weapon system's ability to avoid destruction if it were detected.

Reliable performance of function by all equipment in the presence of hostile factors and effects is essential. But, however clever the design, strong the materials or convincing the claims, no flaws can hide from the probing fingers of nature and no physical structure will escape the consequences of being inadequate.

DATA REQUIREMENTS

Apart from a need to realize that extremely challenging environmental problems exist, is the concern for determining what the environmental factors and effects will be in sufficient detail to permit an engineering approach toward development of essential equipment and the continual extrapolation of data to keep pace with fast-moving developments in the weapon systems field. The key is that vehicle design and propulsive power requirements are the major factors determining the physical environment peculiar to each vehicle and its particular operating circumstances. The engineering data required to determine most of the continually transient physical conditions during a mission are:

- Vehicle configuration, dimensions, compartmentations
- Operational requirements and capabilities
- Propulsive power requirements and characteristics
- Vehicle airflow characteristics
- Skin heating effects and cooling methods
- Detailed distribution of propulsive power
- Aircraft structural factors affecting the design and placement of subsystem equipment
- Materials of construction and their radiation properties
- Operational limitations to the use of transparent materials on exposed surfaces
- Engine arrangements
- Powerplant characteristics
- Chemical composition of engine exhaust
- Radioactivation of the environment
- Thermal structure of the wake
- Anticipated mission schedules.

An appeal for caution—The present lack of definitive data, partly due to both indecision as to the most effective types of weapon systems and the fast pace of aeronautical developments, introduces the possibility that much effort may be committed to the pursuit of wrong objectives. Yet, the risk of falling behind or overlooking what may turn out to be the correct solution to a critical problem is so great that no reasonable effort should be spared in keeping pace with the state of the art and exploring every facet of all the pertinent problems as they arise. The consequences of working with incorrect data, however valid or pertinent they may appear to be, or striving toward wrong objectives, no matter how logically and convincingly they are stated, outweigh practically every consideration of expense and effort required to secure correct data and determine proper objectives.

SIGHTING OBJECTIVES

In the development of electromechanical devices to cope with combined environment, the leading effort must bear upon spelling out the objectives, functions, and compositions of the weapon system. The wisdom and necessity of this continuing effort becomes increasingly clearer with experience. It is bound to be tedious, confusing and iterative, embracing a seemingly endless number of considerations, such as:

- Definition of the tactical and strategic objectives
- Definition of the combat environment
- Postulation of system functions
- Postulation of subsystem functions
- Postulation and specification of electromechanical devices
- Postulating the effects of possible countermeasures
- Determination of weapon system survival probabilities
- Weapon system effectiveness predictions
- Determination of subsystem composition requirements
- Specification of subsystem performance requirements
- Equipment weight, space, function, and performance trade-offs
- Determination of vehicle design and equipment installation requirements
- Determination of physical limitations to the range, speed, and striking power of the weapon system
- Evaluation of subsystem equipment design and development bottleneck problems
- Definition of weapon system flight test objectives
- Definition of the combined physical environment as a function of specified mission requirements.

RELIABILITY

A vigorous reliability program designed to appraise sub-

system equipments in the presence of the combat environment, locally created disturbances, and physical hazards must parallel the leading effort. This reliability program will have many facets involving a wide variety of talent skilled in complex analytical and experimental techniques. Its interim objectives should be to maintain a running appraisal of electromechanical device reliability and continually recommend equipment design techniques and other practices that will contribute to even greater reliability. *Its long-range objective should be to achieve premium equipment performance and to express the equipment's reliability in numerical form so that the value can be used in arriving at estimates of survival probability for the whole weapon system.* A meaningful reliability program should cover:

- Definition of reliability objectives
- Determination of reliability criteria
- Determination of data requirements
- Accumulation of pertinent data and its interpretation
- Postulation of analytical methods for reliability prediction
- Verification of analytical methods by experiment
- Monitoring of all influential weapon system development efforts
- Determination of factors that degrade electromechanical device reliability
- Development of techniques of measuring reliability
- Design and performance of reliability tests
- Recommendation of equipment design principles and other practices that will contribute to improved reliability.

PLANNING A TEST PROGRAM

There is critical need for a rigorous test program to predict conclusively the ability of electromechanical components and systems to perform with extremely high reliability. The tests must be conducted under dynamic conditions and in the combined environment. As a bare minimum, the test program should encompass:

- Definition of test objectives
- Pertinent literature search
- Designation of critical problem areas
- Design of tests
- Choice of test facilities
- Component testing
- Equipment testing
- Reduction and analysis of test data.

Definition of test objectives requires complete description of the physical conditions that electromechanical devices and equipment may encounter. A literature search will help determine what has already been done in the testing of components under difficult environmental circumstances; but, at this moment, little help in the form of applicable data should be expected because hardly any valid testing has been done under the combined environmental conditions of high-speed weapon systems.

Problem areas must be designated with a view to conducting tests of components and equipment critical to the tentative choice of weapon system. Once the problem areas have been identified and priority for coping with them established, meaningful tests can be designed.

Design of a test involves precise specification of the numerous environmental factors to prevail during the test and the exact order in which those factors are to be varied. Only then can a logical choice of test facility be made. The criteria for choice of test facility is performance of a required test without interference from other tests being conducted at the same time, undue loss of time before the test is made, cost, and absence of unnecessary decay-time delay. END

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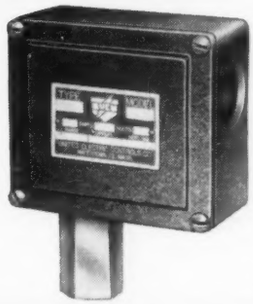

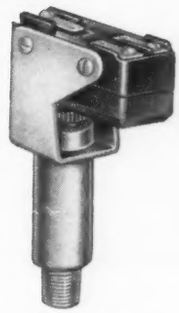

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Report from France

STAFF COLUMNIST

Emile Labin

Emile Labin is President of Automation-Electronique-Recherche Opérationelle in Paris, France.

Gamma Rays Monitor Fluid Densities

Measurement of gamma-ray absorption can be applied to solution of many industrial control problems. SAIP Company, Paris, France, has applied this technique in development of a simple instrument for measuring fluid densities in pipes or for control of chemical concentrations. Figure 1 shows the general arrangement of the measuring equipment. The source of radiations is on one side of the pipe which carries the fluid. The detector and d-c amplifier are on the other side. The amplifier feeds a recording instrument which can be located anywhere.

GAMMA RAY ABSORPTION

If I is the intensity of radiation received by the detector with the pipe filled and I_o is the intensity received with an empty pipe and for the same installation, then:

$$I = I_o \exp [-x (t_A + t_B + \ldots)]$$

where

x is the length of the fluid crossed by the radiation,

t_A, t_B etc. . . . are transmission coefficient characteristics of the chemical elements A, B, C . . . in the liquid, and t is a complex function of the energy E of the incident gamma rays and of the atomic number Z of the element.

For light elements ($Z < 25$) and for usual energies of gamma rays ($50\text{KeV} < E < 2{,}5$ MeV) the coefficient t is simply proportional for a given value of E to the total number of electrons per cubic centimeter or NZ where N is the Avogadro number.

Since the atomic number Z is roughly proportional to the density ρ, then for light elements and for a given energy and a given length of transmission, absorption is a function of density only. The measurement of the intensity received therefore yields the density of the liquid, whatever its chemical formula may be, if we assume that the atomic numbers of all components are not large.

The law above has an important exception: it does not apply directly to hydrogen. Since hydrogen has no neutron in its nucleus, it has twice as many electrons as an equal mass of other elements. In other words the ratio of Z to ρ for hydrogen is double that for other light elements. Thus hydrogen is twice as absorbent as other elements for the same mass.

The table below shows some values of the transmission coefficient for various energies and for some materials.

ABSORPTION COEFFICIENTS

Energies	50 KeV	250 KeV	500 KeV	1 MeV	2,5 MeV
Air	$2.1,10^{-4}$	$1.4,10^{-4}$	$1.1,10^{-4}$	$0.8,10^{-4}$	$0.5,10^{-4}$
Water	$1.8,10^{-1}$	$1.2,10^{-1}$	$0{,}9,10^{-1}$	$0.7,10^{-1}$	$0.43,10^{-1}$
Al	0.9	0.29	0.2	0.16	0.1
Pb	120	6	1.7	0.76	0.48

The figures above are valid only for well focused beams. When the detector can be reached by rays scattered from regions of the liquid not in the main beam, actual transmission coefficients are reduced. To measure the concentration of a heavy element in a liquid, you can choose gamma rays of an energy such that they will be absorbed selectively by that element. As an example, 84 KeV gamma rays (emitted by thalium) will be absorbed much more by heavy elements such as Ba, Pb, or I than by light elements even for equal concentrations.

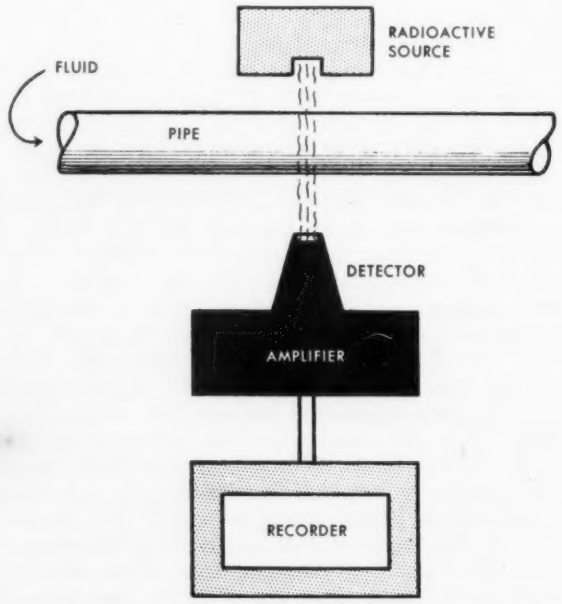


Fig. 1—General principle of densitometer by gamma ray absorption.

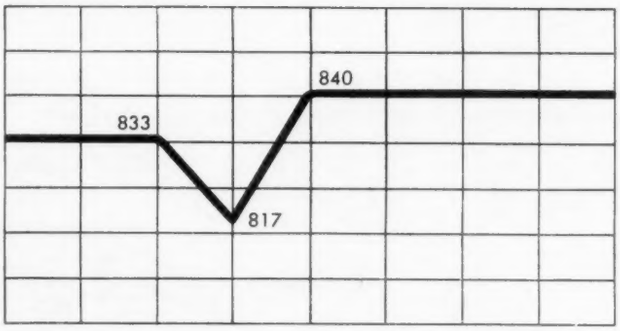


Fig. 2—Recording of change in density of the fluid in a ten-inch pipe-line.

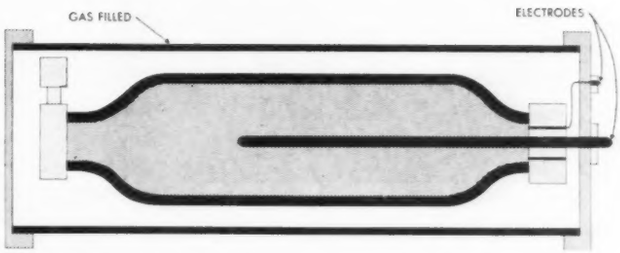


Fig. 3—Principle of high pressure ionization chamber.

SENSITIVITY AND ACCURACY

The ultimate accuracy of measurements by gamma ray absorption depends upon the sensitivity and stability of the detector and upon the statistical nature of the measured quantity. With a source of cobalt 60 and a 25 cm pipe, the intensity will vary by 15 percent when the density varies from 0.6 to 0.9. To detect a change in density of 0.1 percent only, sensitivity of the detector must be $5 \cdot 10^{-4}$.

Two methods are known for obtaining such good sensitivities:

- Detection by scintillation crystal and vacuum photocell cell followed by a d-c amplifier
- Detection by ionization chamber followed by a d-c amplifier.

The SAIP instrument is based on the second method using a special ionization chamber and a d-c amplifier with vibrating capacitor.

Figure 2 shows an actual recording through a 10-inch pipe. The limit in accuracy obtainable and therefore the limit in useful sensitivity is given by fluctuations of gamma ray intensity itself. Radiation emission is indeed a random phenomena. The standard deviation of intensity is equal to the square root of the inverse of the number of photons making up that intensity (when the number is large). In the 10-inch pipe with a 300 millicurie source of cobalt 60, the ionization chamber absorbs approximately 10^6 photons in 10 seconds, which is the circuit time constant of the complete amplifier and recorder system. Standard deviation will therefore be 10^{-3}. In this case then a sensitivity much better than 10^{-3} would be useless.

Three possible ways are available for decreasing the effect of incoming fluctuations:

- Increase the intensity of the source. The limit here, imposed by rules concerning security of operators, is quickly reached
- Increase the circuit time constant. The limit here is imposed by operating conditions. The time constant should be kept smaller than the shortest time required for a change in density. In many cases it would not be safe to go much beyond 10 or 20 seconds
- Increase the efficiency of the detector itself. This is the most promising approach. SAIP has developed for that purpose a special type of ionization chamber.

IONIZATION CHAMBER

Ionization chambers filled with gas under pressure have often been used for gamma ray detection. So far, commercial types have been expensive because of the relative complexity of construction. SAIP has developed a chamber for high pressures, quite simple and easy to build. The general arrangement is shown in Fig. 3.

They use ordinary compressed gas bottles which can accommodate taps on each side. On one side the tap is used to fill the bottle; on the other side a cover is mounted which is a support for the electrodes and has to be air-tight. In the cover are located several inter-leaved conical brass and teflon parts. Under pressure, the teflon is compressed and makes a perfectly tight joint while at the same time it insures excellent electrical insulation for the electrodes; the higher the pressure the better the joint. Chambers of various sizes have been built in this manner with argon or hydrogen under 150-atmospheres of pressure.

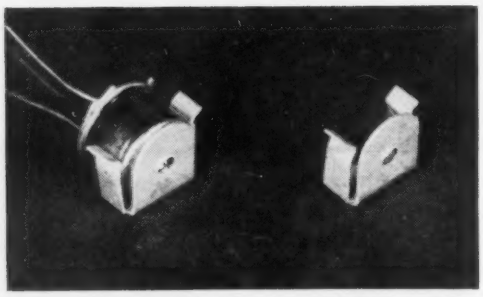
Applications of these chambers are quite important. Used with a good d-c vibrating-capacitor amplifier, these chambers permit detection of the lowest possible fluctuations in radiation. Stability will match this high sensitivitytivity of 10^{-2} to 10^{-4}. When used in absorption densitometers they have the great advantage of requiring only weak signals.

An argon chamber of one liter—61 cubic inches—will be as efficient as a YNa crystal of 70 cm^3. The recording, shown in Fig.2, of radiation through a 10-inch pipe has been obtained with a liter chamber at 150 atmospheres and with a cobalt 60 source of only 10 millicuries. To stay below the legal safe irradiation level one should not approach a source of 50 millicuries of cobalt 60 to less than 9 feet for more than 40 hours per week.

The low power required from the source makes it possible to consider the use of expensive but very long life sources such as radium ($20.00 per millicurie). Sensitivity and stability are such that with the usual cheaper sources having shorter life times, periodic adjustments of scales are required to take care of reduction in intensities.

For cobalt 60 with a half life of 5.3 years, readjustments would be required every month. For Cs ^{137} with a half life of 23 years, resetting every 3 months would be sufficient.

CLIPS for JETEC "30"



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APPLICATIONS

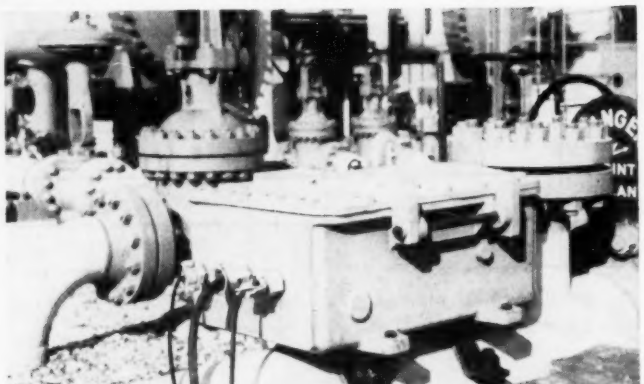


Fig. 4—SAIP densitometer installed on LeHavre-Paris pipe-line.

Fig. 5—Amplifier and recorder for densitometer.

Photographs in Figs. 4 and 5 show an actual equipment installed on a pipe-line from LeHavre to Paris (near Gennevilliers). The equipment identifies the fluids carried by the pipe-line. It includes a radioactive source of 300 millicuries of cobalt 60 in a cylindrical container located just under the pipe-line. A concrete protective enclosure provides for personnel safety.

The ionization chamber and vibrating capacitor preamplifier are inside the pressure and fireprof container shown above the pipe in Fig. 4.

The ionization chamber is filled with argon under 6-Kg/cm^2 pressure. The average d-c current at the amplifier input is $5 \cdot 10^{-11}$ amps. A thermostat has been included in the container. Connection between the preamplifier and the main amplifier is by a 300-foot cable (this is not a maximum).

Amplifier and recording instrument are shown in Fig. 5. Both the amplifier meter and the recorder are graduated in densities from 0.700 to 0.900 with a linear scale. Drift of the complete system is less than 0.002 for 24 hours operation. No supervision is required except to recheck that drift has not exceeded permitted values once or twice every 24 hours. Resetting is done with a potentiometer.

Speed of response—circuit constant—is such that mixtures at the time of change in the nature of flow are completely avoided. The equipment eliminates the need for sampling tests in pipe-line operation.

Control of densities by gamma ray absorption has been achieved with a normal accuracy of 10^{-3}. An accuracy of 10^{-4} is obtainable with special precautions.

The ionization chamber described is well suited for rugged, sensitive, inexpensive installations. It has many applications in control problems, especially in petroleum and chemical industries.

CONTRIBUTING EDITOR

Herbert Kaizer
is Manager of IBM's Experimental Psychology Group, Kingston Military Products Division

HUMAN FACTORS IN SPACE CABIN DESIGN

The rapid development of *human factors* in engineering research and investigation has not been surprising in view of advances in the state of technological arts which have made the human operator the limiting factor in complex rapid-response systems. Two directions are possible under these conditions. One is design of completely automated systems. This way out is usually not possible for a variety of reasons both economic and technical. The alternative direction which is becoming increasingly important is to pay attention to the physiological-psychological capabilities of the operators in the development of complex systems.

At a recent meeting of the American Rocket Society, Dr. E. B. Konecci of Douglas Aircraft Company in a talk on Human Factors and Space Cabin Development said, "'There'll always be a man' is a phrase that has a significant bearing on *human factor* efforts in the conquest of space since the human element is continuously present in the design, construction, servicing and testing of space missiles. In addition, if man is to travel beyond the earth's protective air blanket for a period of days, months and years, an assumption must be made that the engineering and technological problems associated with man's well-being in space can be solved. Then, the prime responsibility of human factors in astronautics will be to insure that the human components in space vehicles are maintained at peak efficiency. One prerequisite for insuring peak efficiency is to provide astronauts with adequate protection against those environmental hazards inherent in orbital exospheric flight and interplanetary travel. Other factors include keeping the space men physically strong, mentally sound, and emotionally stable."

In producing a controlled terrestrial environment for a space cabin crew the technology of pressurized cabins developed for airplanes is inapplicable. Most cabin pressurizations are accomplished with compressed air from the outside of the aircraft and are adequate only for lower atmospheric flight. In the vacuum of space this technique will, of course, be impossible. Research and development activities must, therefore, investigate the feasibility and problems involved in the design of sealed cabins.

In speaking of this research and development, Dr. Konecci said, "Research and development of sealed cabins will supply the engineering criteria to build the space cabins of the future. In addition, human-factors research must be conducted well in advance of the actual space flight test. The reasons for such research were summarized six years ago by General Armstrong, the former surgeon-general of the air force.

"In connection with the November 1951 symposium on the Physics and Medicine of the Upper Atmosphere, he said 'The skill and ingenuity of the aeronautical engineer in designing aircraft with increased speed, endurance and altitude performance have currently projected our flying personnel into the immediate vicinity of an environmental frontier beyond which our knowledge is incomplete, and in some respects, totally lacking. These gaps in our knowledge must be filled in at the earliest opportunity for at least the following reason. A modern, high-performance military aircraft cannot be properly designed until the effect on the crew of the performance of that airplane and the environment through which it will fly is definitely known, because aircrew protective devices must be built-in design features of such aircraft. This consideration points up a fact not generally recognized: that aviation medical research, in this area at least, should be completed prior to the time the aeronautical engineer first sits down to his drawing board, which is usually some five to ten years before the projected airplane is first flown.'

"It is apparent that all of the conditions of space cannot be duplicated on earth. However, most of the factors pertinent to the survival and well-being of the astronaut can be simulated and tested on the ground before the first space flight." Dr. Konecci pointed out a number of government laboratories and industries under government contract were carrying out such investigations. These investigations range from design of space suits to the social and psychological effects of isolating crew members in simulated space cabins.

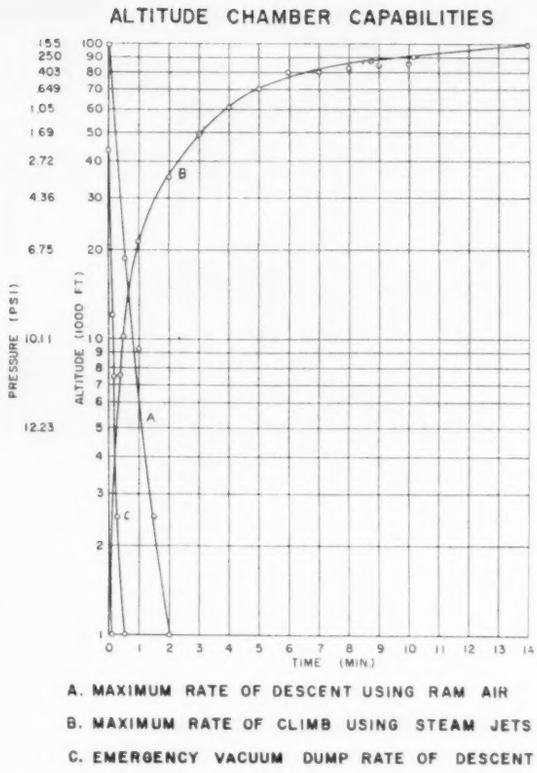
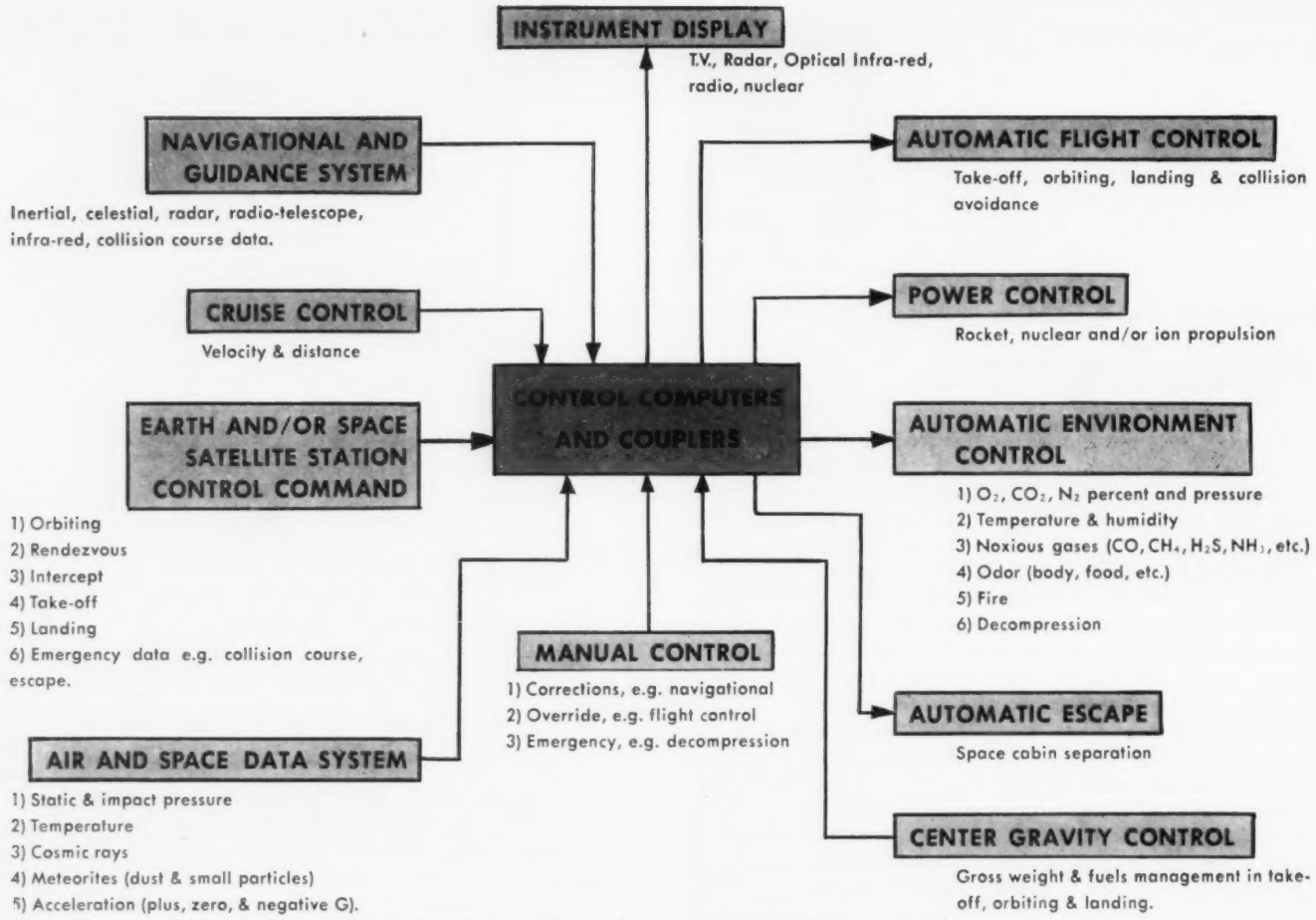


Fig. 1—Altitude performance curves of the Douglas-Tulsa altitude chamber. (Courtesy of the Douglas Aircraft Co., Inc., Tulsa, Oklahoma).

SPACE CABIN RESEARCH

Dr. Konecci's company, the Tulsa division, has developed excellent test facilities especially adapted to sealed cabin research and development work. The Tulsa high-altitude chamber is one of the largest and most versatile altitude chambers in this country, Dr. Konecci reported. The chamber itself is bell-shaped, has a 22-foot inside diameter and can be raised on three hydraulic rams 12 feet off the floor. It contains a master console for automatic or manual control of any program flight from altitudes of 0 to 120,000 feet and temperature variations from +250 degrees to −85 degrees Fahrenheit. Figure 1 is a graph of the maximum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AUTOMATIC FLIGHT CONTROL
Take-off, orbiting, landing & collision avoidance
CRUISE CONTROL
Velocity & distance
POWER CONTROL
Rocket, nuclear and/or ion propulsion
CONTROL COMPUTERS AND COUPLERS
EARTH AND/OR SPACE SATELLITE STATION CONTROL COMMAND
1) Orbiting
2) Rendezvous
3) Intercept
4) Take-off
5) Landing
6) Emergency data e.g. collision course, escape.
AUTOMATIC ENVIRONMENT CONTROL
1) O_2, CO_2, N_2 percent and pressure
2) Temperature & humidity
3) Noxious gases (CO, CH_4, H_2S, NH_3, etc.)
4) Odor (body, food, etc.)
5) Fire
6) Decompression
MANUAL CONTROL
1) Corrections, e.g. navigational
2) Override, e.g. flight control
3) Emergency, e.g. decompression
AUTOMATIC ESCAPE
Space cabin separation
AIR AND SPACE DATA SYSTEM
1) Static & impact pressure
2) Temperature
3) Cosmic rays
4) Meteorites (dust & small particles)
5) Acceleration (plus, zero, & negative G).
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Fig. 2—General parameters of automatic controls in space vehicles.

rate of climb of this chamber. The advantages of this altitude chamber were reported by Dr. Konecci in the following points.

"1. It is possible to simulate the near space conditions of 120,000 feet (0.0628 psi) indefinitely, without leaving the ground

2. Tests can include extreme conditions with safety

3. Chamber tests save the high cost of extensive flight tests

4. Instrumentation affords an unlimited number of tests to be conducted simultaneously under controlled conditions

5. Designs can be tested, changes made, and retested, quickly and economically

6. The space cabin can be control tested as an integrated unit including the human."

IDEAL CABIN CONDITIONS

Dr. Konecci reported that an ideal hermetically sealed space cabin must be a closed self-contained system. Design of such a cabin must take into consideration the following conditions. The cabin should have zero leakage of atmospheric gases at a pressure differential of 14.7 psi. The structure itself must withstand prolonged exposures to such pressure differentials. Concentration of gases should be kept at approximate sea level conditions on earth. In addition, these conditions should be automatically controlled with the possibility of manual override. The problems of water conservation and reclamation and facilities for personal hygiene become extremely important as flight duration increases. Problems of weightlessness and the isolation of crews for extended periods of time must be considered.

In all probability the controls of space vehicles will be automatic. The requirements, then, on the reliability of such controls is extremely important. Figure 2 reproduces the general parameters of automatic control booths in space vehicles considered important by Dr. Konecci. Although these controls will have as their normal mode of operation an automatic mode, the human occupants of the space craft should act as monitors and possible overriders of these controls. Therefore, the design of sensible instrument panel displays and simple positive controls must be considered.

ARTIFICIAL ATMOSPHERE IN SPACE CABINS

Dr. Konecci's work has been primarily concerned with the problems of an artificial atmosphere of a hypothetical space vehicle. His computations have shown that a crew of five in such a space vehicle would use 1,483 liters of liquid oxygen in one year, this oxygen occupying about 55 cubic feet of cabin space. Even more important is the control of carbon dioxide concentrations in such an atmosphere. Studies of submarine crews have shown that concentrations as low as 4 percent over extended periods of time have irreversible toxic effects.

In discussing this problem of the generation of an artificial atmosphere, Dr. Konecci said "Undoubtedly the payload and storage volume of a space cabin will be limited so that other means of supplying the crew with their oxygen needs and carbon dioxide elimination should be considered.

"Photosynthesis is the natural way of producing oxygen on the earth. The oxygen used up in the respiration of plants and animals is restored through the process of photosynthesis. Green plants with chlorophyl convert solar energy and carbon dioxide into chemical energy of the structural material of the plant and release oxygen in the process.

"Some investigators have suggested the use of green algy in the space cabin as a photosynthetic gas exchanger. At

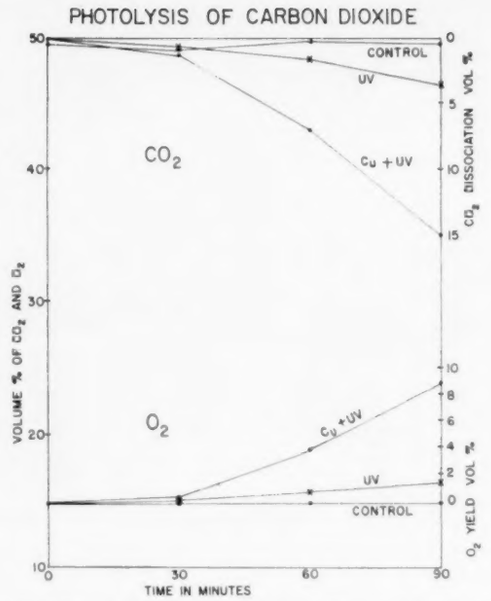

Fig. 3—Graphic results of the three treatments: control copper alone, ultraviolet radiation alone, and copper catalyst and ultraviolet radiation.

present, the volume of 80 cubic feet per man, the large illuminating surface power requirements and heat dissipation of such a green algy (chlorella) gas exchanger make it impractical. In view of this Dr. Konecci suggested that another system might be considered at this time for at least a partial recovery of oxygen by decomposition of respiratory carbon dioxide.

The proposed system involves the production of oxygen from the photolysis of carbon dioxide with ultraviolet radiation and a catalyst. The catalyst in this system is copper. The optimum decomposition of CO_2 is obtained at a pressure of 300 millimeters in the presence of a very small proportion of water. Dr. Konecci has completed a series of 20 experiments using three experimental treatments: control copper catalyst only, ultraviolet radiation only, and the combination of ultraviolet and copper catalyst.

At the start of each experiment the concentration of carbon dioxide was about 50 percent and oxygen about 15 percent with the addition of a small amount of water vapor. In each treatment gas samples were taken at 0, 15, 30, 45, 60, 75, and 90 minutes after the start of the experiment and analyzed by the Haldane method. After the completion of each 90 minute experiment, a sample of gas was tested for carbon monoxide by using the pyrotanic acid method.

The results of these analyses did not reveal the presence of carbon monoxide. Figure 3 is a graphic representation of Dr. Konecci's test results. It shows that with the copper catalyst and ultraviolet radiation, a mean dissociation of 15 vol percent carbon dioxide and a mean yield of 9 vol percent oxygen occur at the end of the 90 minute treatment. Such a system, then, represents a promising step forward.

Dr. Konecci's report and the general problem of space cabin development are excellent illustrations of the broad spectrum of techniques and sciences involved in human-factors engineering research. Indeed, these techniques and sciences range all the way from molecular biology to physical and cultural anthropology. If the excellent work of Dr. Konecci and his colleagues and other investigators involved in this area of research is to have its fullest use, it will be necessary to develop teams of specialists in the various life sciences and engineering sciences involved and permit these teams to work on such problems full time with the use of the various technologies at their disposal.

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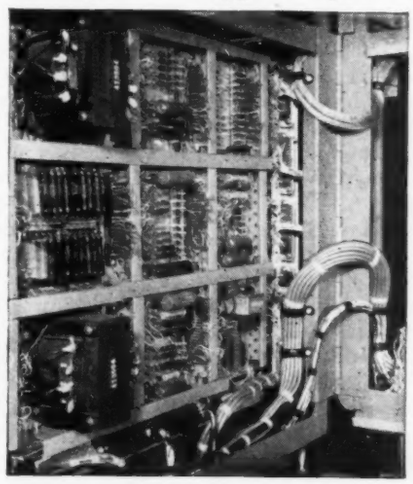

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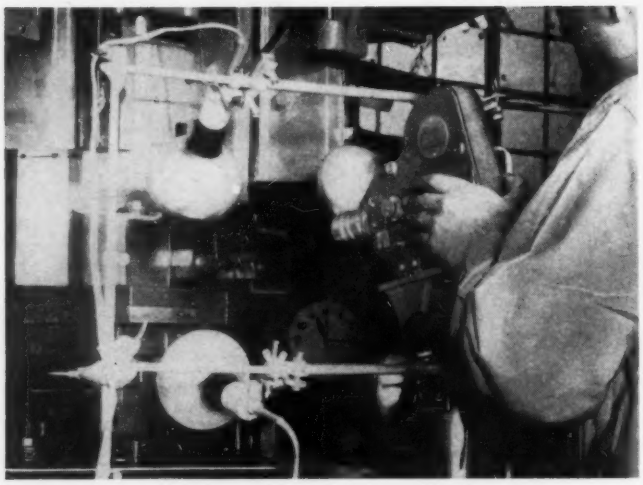
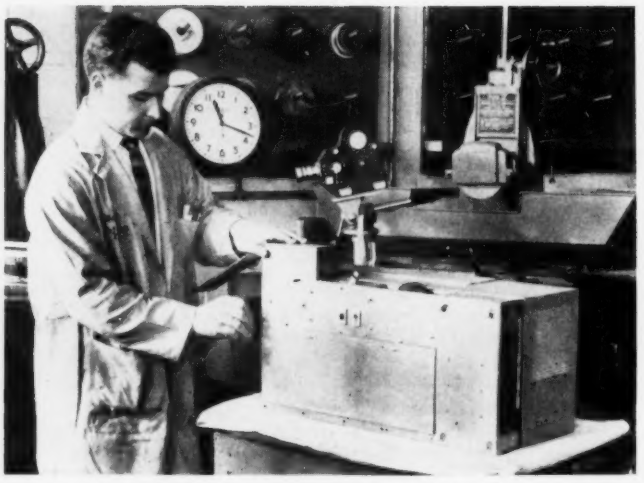


Allowing 15 minutes for set-up time, research engineer is ready to analyze photographically a punch press operation. The time is now 11:15 a.m. Test set-up will record shock, shear and tear characteristics of a new titanium alloy.



Now, three minutes later the daylight loading film spool is dropped into the feeding compartment of Fairchild's new film processor. Completely automatic and leaderless operation enables the operator to merely feed the first two inches into a slot in the compartment.

RAPID FILM PROCESSOR

From Test to Film in Twenty Minutes

For years scientists and engineers have had to rely on commercial processing laboratories for the development of 16mm and 35mm motion picture recording films. Delays of hours, days and even weeks occurred between the time of exposure and the return of the processed film from the laboratory. In many cases this delay either made the films obsolete or showed an error in the original set-up which required a complete reshooting.

Requirements for high speed movies, oscilloscope records, gun camera and missile films, and many other types of photographic instrumentation are such that the film must be viewed as soon as possible after the recorded event has taken place. Otherwise their evaluation may be useless and cause expense and frustration.

Need for an interim processor which could be used at the shooting location and which would not require skilled photographic personnel prompted Fairchild Camera and Instrument Corporation to conduct the necessary research and development required to produce such a unit. Designated "Mini-Rapid 16", Fairchild's engineers have designed a complete automatic, self-threading, tabletop processor capable of turning out one hundred foot rolls of 16mm film, processed and dried in less than 20 minutes.

Major elements in the tiny processor about the size of a standard file drawer are the easily interchangeable film transport plastic inserts containing a high speed developer, a rapid fixer, a hypo eliminating agent and a static rinse. Provisions have also been made for the use of an accessory tank for circulating water. Drying is carried out by a high velocity air jet on the emulsion side of the film. The resultant film is of commercial quality. In addition more permanent quality is obtained by running the film through a second time with the tanks filled only with water. The unit has a wide range capacity in film length and longevity of chemical solutions. Film lengths as short as one foot or as long as 400 feet may be processed without the necessity of changing or replenishing the chemical solutions.

Weight of the "Mini-Rapid 16" is 70 lbs. dry. Size is 27″ long, 12″ wide and 13″ high. Manual operation of the unit begins with the placement of exposed 16mm film in the film compartment. Daylight loading spools are placed directly in the processor while special magazines require spooling on daylight loading spools. Film loads larger than 400 feet must be respooled or make use of accessory 1,000 foot cassette. After insertion of the film into the entry port, with emulsion side down, the film supply compartment is closed and the film automatically threads itself through the processor to the take-up compartment, a trip of approximately 6 feet and 8 inches.

Rubber rollers on the plastic insert assembly serve a triple function—drive rollers for film transport, as a means of agitation, and squeegeeing the exhausted solution back into the solution container, thus reducing solution carryover from one tank to another. Rollers are on floating shafts and the shafts are retained against the driven center drum by means of an elastic member. The film is guided in its path by grooves in the sides of the plastic inserts. Once the film passes between the rubber rollers and the center drum it is automatically transported to the next rubber roller and on through each insert.

Drying of the film is effected by impingement of heated air on the emulsion side of the film. The base side of the film is held against a driven fabric belt by means of the air blower which assists in the transport of the film on the drier.

Take-up, the second manual operation is accomplished by attaching the leading edge of the processed film to a standard daylight loading spool and dropping the spool into the take-up compartment where it rides on a rubber covered film spool which is slightly over-driven. This method takes up the film firmly and ready for projection.

A variable speed film drive system makes it possible to adjust the rate of processing for over and under-exposed and/or temperature variations. The film may be checked for degree of development at the take-up spool and the speed adjusted to compensate for any errors in exposure. Thus the control may be used to pre-select a specified degree of development when all the other factors are known.

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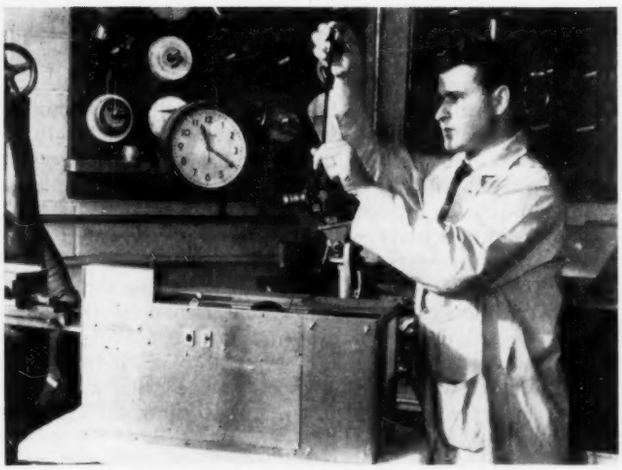

At 11:20 a.m. the first few feet are emerging, dry and ready for inspection. The operator examines it for proper development and can make any adjustments to compensate for exposure or chemical temperature variances. To do this he merely turns the drive speed control knob.

At 11:34 a.m. the 100 foot roll of 16mm film emerges completely developed, ready for projection. It travelled at the rate of 6 feet per minute through the film processing device, but speeds as fast as 10 feet a minute are possible.

Only 23 minutes after shooting pictures, the film is projected and the operation is subject to the analysis of the critical eyes of design and test engineers.

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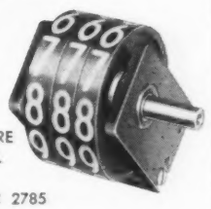

MINIATURE INTERNAL PINION COUNTER 2785

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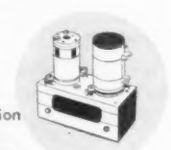

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CIRCLE 26 ON INQUIRY CARD

NEW TECHNIQUES

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MATERIALS ANALYSIS

From The Gnat's Eye On Down

In most instances, research on materials performance comes up against the problem of evaluating chemical changes in a system. Changes in electrical properties, in particular, can be affected grossly by relatively minute changes in chemical composition. One might characterize solid-state research as the study of minute impurities. These minute impurities have a dramatic effect on the lattice effects of a system which determine the performance of phosphors, semi-conductors and dielectrics. In atmospheric polution studies, trace quantities of gaseous and solid particles have been found to affect the smog-producing potential of the atmosphere. Much of the extensive and detailed work on nuclear transformations has been possible only because techniques of measuring extremely small quantities of materials had been developed.

Justus von Liebig used to say, "To measure is to know." The new techniques of analysis have pushed the limits of analysis back orders of magnitude. The old "gnat's eye" limit is now a pretty gross quantity to the modern analyst. The measurement of quantities in the order of 10^{-12} grams is quite practical in many cases and the information available from these analyses permits us to "know" more about such diverse matters as diffusion in metals, the age of an Egyptian mummy and the composition of cigarette smoke.

No single technique is the answer to all analytical measurements. Each procedure has its own advantages and limitations. The most sensitive techniques are in three broad categories: radioactivity, spectroscopy, and the mass spectrograph. Under optimum conditions, the radioactive techniques are potentially the most sensitive. The ultimate limit of sensitivity is governed only by the specific activity of the particular radioisotope being measured. Assuming the use of ordinary ionization chambers or Geiger–Muller tubes, we can estimate the ultimate sensitivity of measurement of radioisotopes. The minimum detectable weight can be shown to be $10^{-23} \times T \times A$, where T is the half-life in seconds and A is the atomic weight. For carbon 14 used in the radiodating of ancient artifacts this minimum detectable weight works out to be 2.5×10^{-11} grams. Because of this high sensitivity, it is possible to date a carbon-containing artifact back as far as 35,000 years with an accuracy of 100 years in the middle of the range. With radio-phosphorous which has a half-life of 15 days, the minimum detectable weight turns out to be 4×10^{-16} grams. This extreme sensitivity of detection and measurement points out the reason why radioisotopes are so effective as tracers in the study of diffusion, wear, corrosion, and biological processes where extremely minute amounts of actual material are transferred. More elaborate counting techniques extend the limits of measurement by more than an order of magnitude. By the use of proper counting chambers, tritium the radioactive isotope of hydrogen can be measured in concentrations as low as 10^8 atoms per gram of water. Based on the weight of water, this is 3.7×10^{-15} grams or 3.7×10^{-13} percent.

One interesting application of radioisotope tracing is the study of diffusion of material from a gold-plated tungsten whisker into germanium during the process of forming by a voltage pulse(1). The tungsten whisker was plated with gold 199, an artificially produced radioisotope of gold, and pulsed in contact with a germanium crystal. Radioactivity measurements showed that a total of 10^9 atoms or 3.3×10^{-13} grams of gold was transferred into the crystal. The distribution of the gold was determined by autoradiographic techniques. After exposure to film a thin layer of the crystal was lapped off and rephotographed. It was found that the gold was distributed in a cone with a base of about 100 microns diameter and a depth of 2.5 microns in the crystal.

Autoradiography—A Simple and Useful Tool

Autoradiography has been used extensively in metallurgical investigations and piston ring wear studies. The technique is extremely simple and provides exact information on distribution not obtainable by the usual counting procedures. The sample to be examined is simply placed in contact with a piece of photographic film for the appropriate length of time, depending upon the activity of specimen, and the film is developed. The radioactive portions will show up as isolated darkened spots or broad areas. This technique has been used to determine the distribution of components in alloys and the changes in distribution caused by heat treatment or other metal treating processes. In piston ring wear studies, autoradiographic examination of the cylinder walls showed that maximum wear occurred in the areas closest to the end of the piston travel, where lubrication was least effective.

Moisture transmission and penetration into dielectrics can be studied very simply and rapidly by the use of tritium-enriched water. Tritium is readily available and can be traced easily by autoradiographic techniques as well as by standard counting procedures. For the simple case of determining moisture penetration into an insulator, the insulator is immersed in tritium-enriched water. After the selected time of immersion, the insulator is dried, sectioned, and placed in contact with film for a period of 2-24 hours depending upon the activity of the system. The darkening of the film on development produces a graphic record of the relative rate of moisture penetration.

For example, this technique was applied to the following problem. A fabricated cylindrical insulator, which was suspected of breakdown by moisture absorption, was immersed to a depth of ¼ inch in a beaker containing tritium-enriched water. After 24 hours the insulator was removed and sliced down the length of the cylinder. One section was then placed on a piece of film for three hours. The darkened section showed the degree of penetration of liquid moisture into the rod and extent of transmission of the moisture. Extension of this technique to water vapor absorption and leak detection is quite obvious.

Tritium can also be introduced readily into organic compounds, such as solvents, plasticizers, coatings, and resins. The high specific activity of tritium, more than 2000 times that of carbon 14, reduces exposure time to a matter of hours in place of the days and weeks necessary for carbon 14. Studies of solvent release, plasticizer compatibility, plasticizer migration, and other factors that affect insulation efficiency can be studied in a simple and straightforward manner by modestly equipped laboratories and solve problems that would ordinarily require extensive facilities for investigation.

1. M. W. Aarons, M. Pobereskin, J. E. Gates, E. B. Dale, Phys. Rev., 95, p. 1345.

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New Machine Kit for Proving Designs

A unique new machine construction kit designed to enable engineers, machine designers, scientists, inventors and automation specialists to make precision working models of practically any type of machine, drive or mechanism is now available.

It uses a basic construction concept of round rods and beams that are assembled into frameworks by rugged clamping means. A wide variety of precision-machined mechanical components such as ball bearings; spur, bevel, internal and worm gears; gear racks; ratchets; sprockets; pulleys; sheaves; couplings; springs; wheels; disks and universal joints are used in the system.

Using standard kit components, you can construct smooth-operating, precision-detailed mechanisms such as reciprocating motions, slide motions, geared transmissions, differentials and coil-spring devices.

In addition to permitting the development of new ideas and creation of machines and mechanisms in design work, models made with the kit can be used to prove and sell mechanical concepts, or as machines and test equipment for doing research and development work.

The system was created by a Swedish inventor named Mark Sylwan, who saw a great need by industry for an accurate method of constructing and proving machines and mechanisms that would avoid large development program expenditures where principles had not been thoroughly substantiated.

Many Swedish and English firms have already made extensive use of the system; some have built models of huge log saws, travelling cranes, articulated rail cars and rotary printing presses to prove designs before blueprints were finalized and construction started.

The kits are in two sizes, each supplied with complete instruction manuals. The FAC-X1 kit, selling for $250.00, has 2,700 parts and is intended for student engineers as well as professional engineers. The FAC-X2 kit, selling for $400.00, has 4,700 parts especially selected to meet industrial machine design and development requirements.

FAC kit components are precision-made in Sweden to exacting tolerance specifications. Extra parts for expanding the basic kits can be catalog ordered for delivery from warehouses in the United States. The kits are obtainable from FAC Division, Detroit, Michigan.

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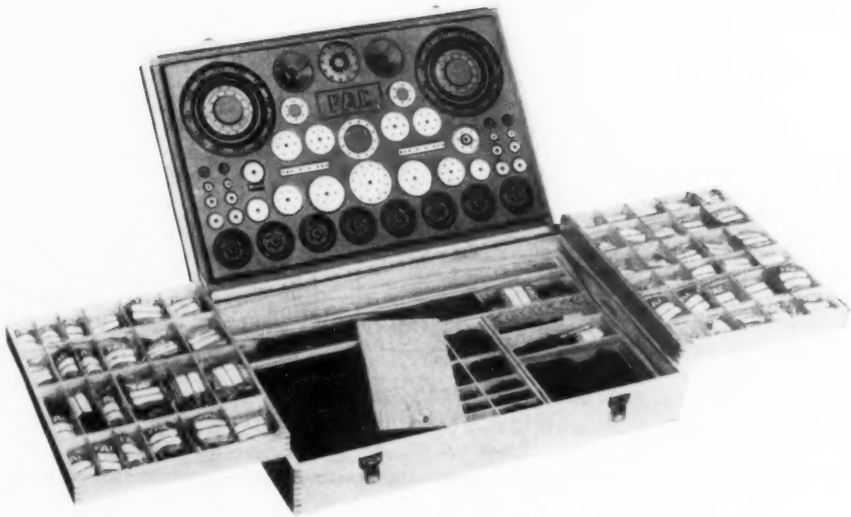
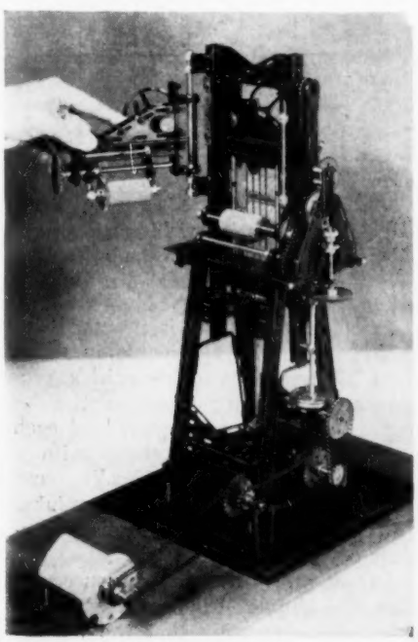
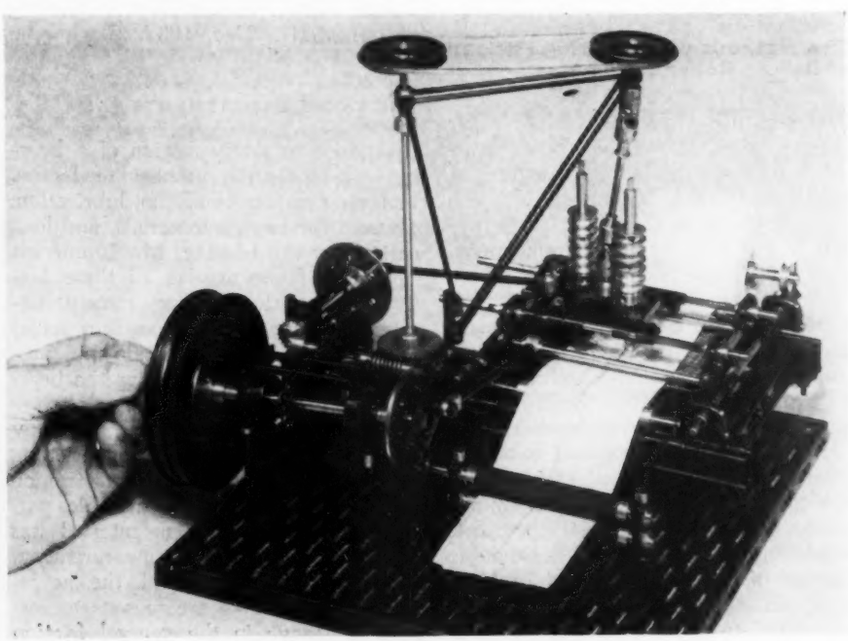


The FAC-X2 Kit.



A FAC working model of a log saw.



A FAC ball-point pen tester.

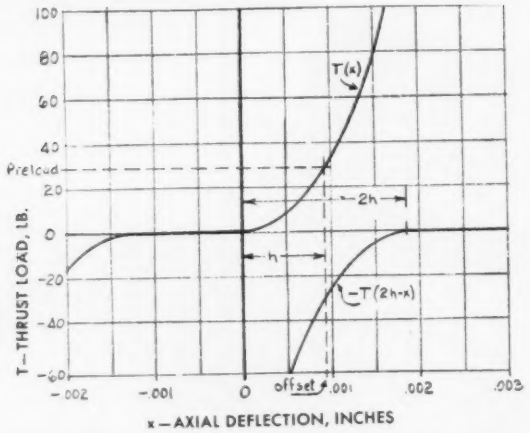


Fig. 2—Load versus deflection curve.

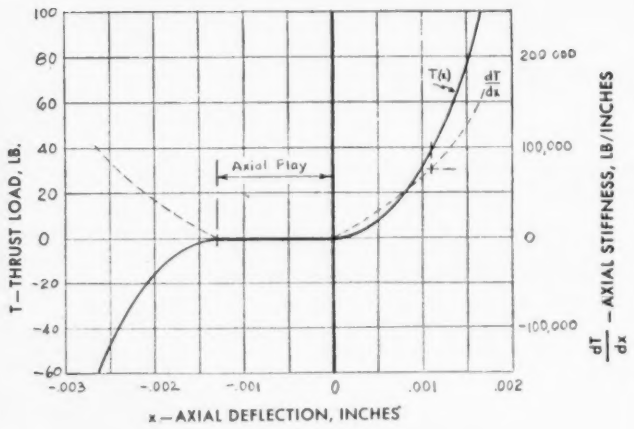


Fig. 4—Bearing deflection curves.

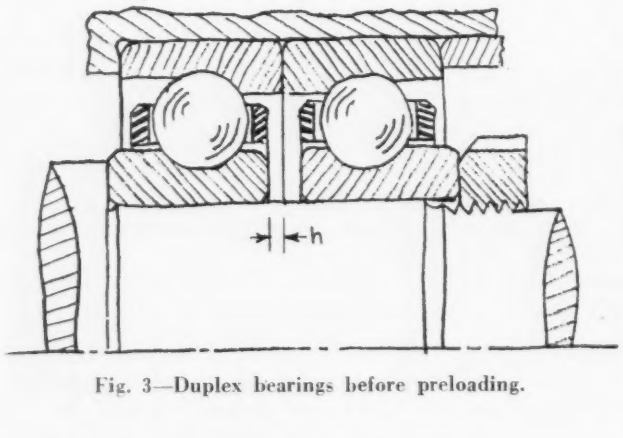


Fig. 3—Duplex bearings before preloading.

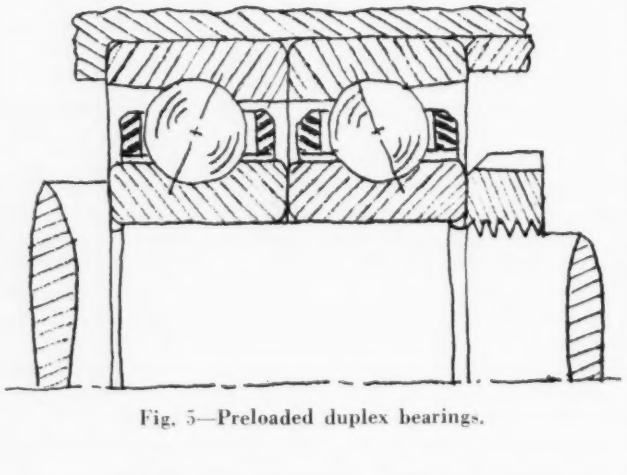


Fig. 5—Preloaded duplex bearings.

PRECISION BEARINGS

Two methods of Measuring Preload of Ball or Roller Bearings

Designers use preloaded ball or roller bearing pairs, known as *duplex bearings*, to maintain a high degree of radial and axial alignment between machine elements. These bearings present a problem in those applications, such as in precision instruments, where friction torque about the bearing axis is required to be exceedingly small, since preloading to increase stiffness also increases friction. Careful design is required to attain the best compromise between these two characteristics.

But the actual preload of a duplex bearing may differ considerably from the design value because of minor changes in clearances, temperature, alignment, and so forth. A dependable method of measuring preload is therefore indispensable in fabrication of high quality instruments using preloaded bearings. Two such methods were described by Claude L. Emmerich of Norden-Ketay Corporation, White Plains, N. Y., at the Annual Meeting of the ASME, Dec. 1957.

FRICTION MEASUREMENTS

Resistance to rotary motion of a bearing depends on a number of factors including surface condition, lubrication, presence of foreign materials, and load carried by the bearing. Mr. Emmerich said that if you assume all these factors except the loading remain unaltered, you can deduce the actual bearing preload from friction measurements made before and after the bearings are assembled.

He cautioned that since so many factors contribute to bearing friction, deduction of preload from friction measurements is not very reliable, particularly if a long time interval has elapsed between the pilot measurements and the determination of the actual preload, or if there are reasons to suspect a change in the general friction characteristics. "Nevertheless," he said,

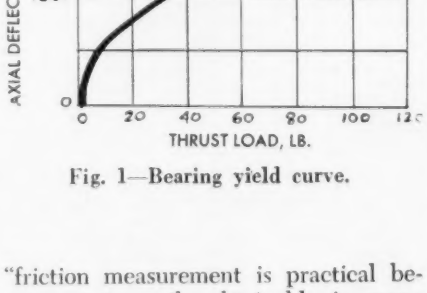


Fig. 1—Bearing yield curve.

"friction measurement is practical because it is easily obtainable in many cases." Here is Mr. Emmerich's procedure for friction measurement. Prior to final assembly of the pair, load each bearing individually, perhaps with a dead weight or hydraulically, and measure the friction by determining the coast-down time of a mass supported by the bearing.

Repeat this friction measurement after the duplex bearings have been assembled. Assuming that the friction torque is directly proportional to the

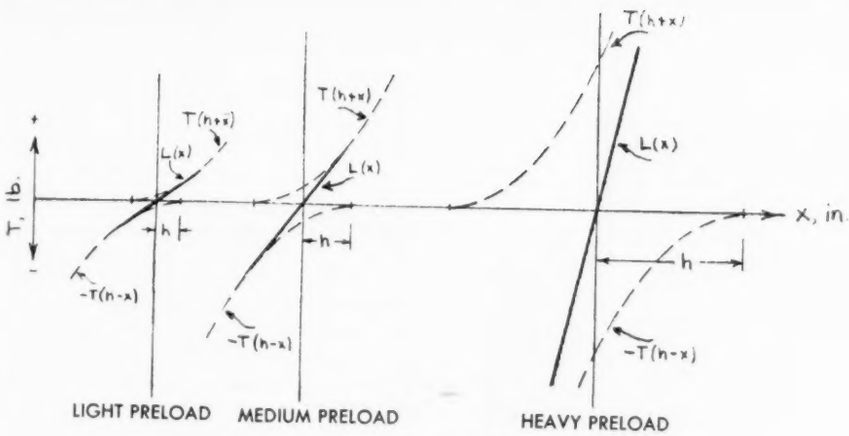


Fig. 6—Deflection curves of preloaded bearing assembly.

load on each bearing, calculate the preload of the assembled pair.

For example, a single bearing supporting a 1.0-pound weight might exhibit a friction torque of 0.2 ounce-inch as measured by permitting the weight to coast down to a halt from a known initial speed. Assume that two such bearings are assembled as a duplex pair with a design preload of 1.5 pound. Since each of the bearings contributes a fricton torque corresponding to a thrust load of 1.5 pound, friction torque of the assembly should be $2 \times 1.5 \times 0.2 = 0.06$ ounce-inch. If the actual friction torque is found to be only 0.04 ounce-inch, the bearings are operating with a 1.0 pound preload.

DISPLACEMENT MEASUREMENTS

"The primary purpose of preloading a bearing pair," Mr. Emmerich pointed out, "is to control displacements of the members supported by the bearings as external loads are applied. Direct measurement of these displacements is therefore a preferred method for determining preloads although bearing deflections as a function of load are normally very small so that accurate measurements are difficult to execute."

He said that bearing deflections caused by loading are usually plotted as yield curves, with the load as the independent variable. Figure 1 is an example of the axial yield of a single bearing, plotted in the conventional manner. "While it is true," he said, "that axial deflections are caused by thrust loads imposed on the bearing, and that the load therefore should be considered as the independent variable, analysis of the action of a preloaded pair of duplex bearings is simpler if axial displacement of the bearing races with respect to each other is plotted as the abscissa, and the corresponding load as the ordinate." In Fig. 2 the deflection curve plotted in this manner is extended to include negative forces, showing the axial play of the bearing. This type of curve has the desirable property that its derivatives remain finite.

For example, Mr. Emmerich pointed out that the slope of the curve dT/dx, representing axial stiffness of the bearing, is seen to be zero in the region of axial play and to rise continuously as the bearing is loaded in either direction. The deflection curve can be developed into a power series

$$T(x) = a_0 + a_1x + a_2x^2 + a_3x^3 + \ldots, \quad x \geqq 0 \qquad (1)$$

"If two bearings are assembled back-to-back as shown in Fig. 3, and Fig. 2 is taken as the deflection curve of the left bearing $T(x)$," he said, "then the deflection curve of the right bearing is $-T(2h\text{-}x)$, where h is a constant associated with the initial separation of the bearings." Both $T(x)$ and $-T(2h\text{-}x)$ are plotted in Fig. 4. The distance h is defined as the "offset" of each bearing.

"Tightening up on the bearing assembly, until the inner races touch as sketched in Fig. 5," he said, "loads both bearings by the same amount in opposite directions and displaces them by equal amounts in opposite directions." Hence the operating point of the duplex pair is the point for which

$$/T(x)/ = /-T(2h\text{-}x)/ \qquad (2)$$

This point has the abscissa

$$x = h \qquad (3)$$

Mr. Emmerich suggested that the origin be shifted to this point, so that the bearing-deflection curves may be written

$$T(h+x) \text{ and } -T(h-x) \qquad (4, 5)$$

The external load $L(x)$ supported by the duplex bearings is the sum of the thrust forces carried by the bearings individually

$$L(x) = T(h+x) - T(h-x) \qquad (6)$$

Figure 6 shows typical plots of this equation. Mr. Emmerich indicated that one of the significant characteristics of the deflection curve for the duplex bearing pair, $L(x)$, is its linearity near the origin. Substitution of the Power Series (1) in Equation (6) shows that $L(x)$ contains only odd powers of x

$$L(x) = b_1x + b_3x^3 + b_5x^5 + \ldots \qquad (7)$$

"A duplex-bearing pair therefore possesses characteristics analogous in some respects to those of a push-pull circuit in electronic amplifiers," he said.

"For small values of x, the coefficient b_1, representing the slope of the curve $L(x)$, or the axial stiffness of the bearing assembly, is the only significant quantity." Since the slopes of the component curves $T(h+x)$ and $-T(h-x)$ are equal at $x = 0$, the slope of $L(x)$ is just twice the slope of the deflection curve of a single bearing at $x = 0$. In other words, the stiffness of the bearing pair is twice the stiffness of a single bearing.

"Hence," he said, "you can find the actual preload of an assembled duplex-bearing pair by locating on the single-bearing deflection curve the point that has one half the slope of the deflection curve $L(x)$ of the assembled pair."

For example, he pointed out that a measurement of the yield rate of an assembled pair might show that the deflection curve $L(x)$ has a slope of 150,000 pounds/inch. Yield measurements made on single bearings established the deflection curve shown in Fig. 2. The bearing pair is therefore preloaded to a point where the single-bearing curve has a slope of 75,000 pounds/inch. This is seen to be the case at approximately 40 pounds. Thus the preload in this example is 40 pounds. END

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Four methods of measuring speed to one tenth of one per cent accuracy are described in a new brochure. Methods are applicable to continuous process industries such as paper, steel, chemical, rubber, textile and similar plants.

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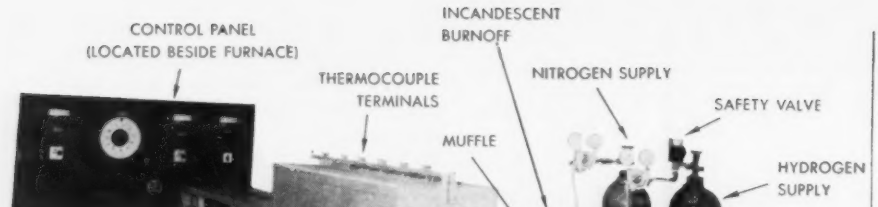

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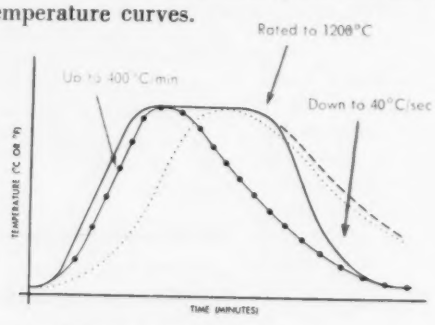

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NEW TECHNIQUES

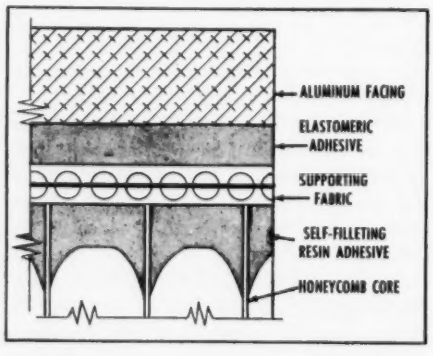
HONEYCOMB SANDWICH CONSTRUCTION

New Adhesive Films Make Strong Panels

A new series of heat curing supported composite film adhesives for honeycomb sandwich construction provide the highest combination of peel and beam-shear strength, and reduce production costs for high strength sandwich panel construction, according to the manufacturer.

Two of the adhesives in this series, designated as SCOTCH-WELD Brand Bonding Films AF-200 and AF-201, are now available. They consist of a high strength elastomeric adhesive film on one surface and a self-filleting adhesive film on the other. The elastomeric adhesive bonds to the facing and the self-filleting adhesive bonds to the core of the honeycomb sandwich panel. This new concept permits the formulation of adhesive films that provide the highest combination of peel strength and beam shear strength at service temperatures ranging from minus 70 to plus 250 degrees F.

In recent field evaluations, composite adhesive film AF-200 produced high strength aluminum honeycomb sandwich panels with beam shear, flexure strength of 1580, 1530 and 1385 psi at temperatures of minus 67, plus 80 and plus 180 respectively. In all cases, failure of the panel was caused by core delamination and not by adhesive bond failure. Aluminum honeycomb panels bonded with this adhesive have peel strengths of 18, 24 and 21 inch-pounds per inch at minus 67, plus 80 and plus 180 degrees F respectively.



Cross section of typical bonded honeycomb sandwich panel illustrates the bond produced by the 3M supported composite film adhesive. High strength elastomeric adhesive bonds to the facing and the self-filleting adhesive bonds to the core of the honeycomb sandwich panel.

Beam shear flexure strength evaluations were conducted according to MIL-C-7438B specification. Peel strength evaluations were conducted according to recently proposed honeycomb specification MIL-A-25463 (USAF).

Supported composite film adhesives eliminate the need for sandwich core priming which requires time, manpower, priming equipment, air drying racks, force drying ovens and storage space for priming equipment.

Like other film adhesives, composite supported film adhesives provide: (1) uniform adhesive thickness between the core material and reducing weight of the final assembly; (2) controlled adhesive confinement to the immediate bonding area; (3) clean bonding operations; and (4) simple application procedures. Because these film adhesives do not contain any solvent, waste and shrinkage are avoided and solvent hazards and drying problems are eliminated.

APPLICATION AND BONDING PROCEDURE

A clean, dry, grease-free bonding surface is necessary for the development of high strength bonds. Metal surfaces must be sufficiently clean to sustain a continuous water film.

Aluminum facings can be cleaned by scrubbing in acetone or acid-etched for 10 minutes and thoroughly dried.

Aluminum honeycomb can be cleaned by soaking in aliphatic naphtha or immersed in chemical etching solutions for a short period of time and thoroughly dried.

The bonding procedure begins with cutting the composite film adhesive to fit the bonding surface. Care must be taken to see that the film is not contaminated by dirt or moisture. The film is then placed between the core and facings and the components assembled. The assembly is then bonded in a heated press at a temperature of 350 degrees F and 50 minutes under a pressure of 25 psi.

These new films are available from the Adhesives, Coatings & Sealers Division, Minnesota Mining & Manufacturing Co., Detroit, Michigan.

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WORTH FILING

Germanium Component Rectifiers

A six page bulletin tells you how to select and apply fan-cooled and blower-cooled germanium rectifiers. Tables, charts, line drawings and photographs.

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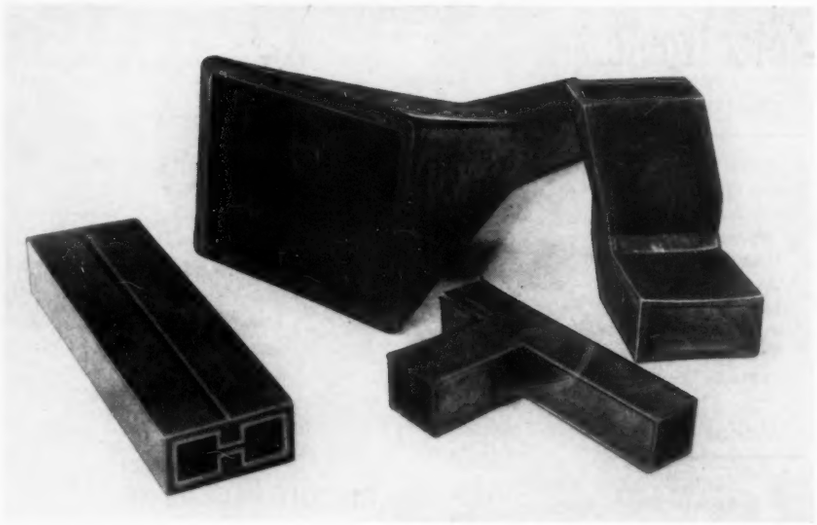
Electroforming



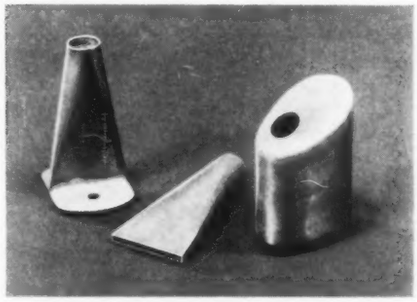
Laminates of metal to metal can be produced in various thicknesses by depositing one metal over another.

New Latitude in Design

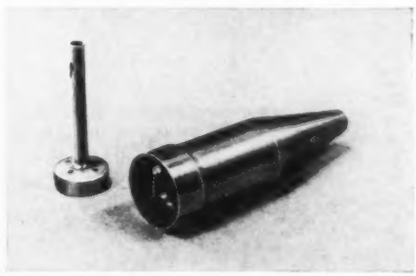
Improvements in electroforming, a relatively new production technique, now permit this process to be applied to the production of high precision electro-mechanical components. It is now used in the production of metal shapes, especially those of tubular, conical or cup-like parts, more economically than by deep-drawing or other operations involving more than a simple swedging or stamping.

Basically the electroforming process involves the electrodeposition of a layer of metal on a master mandrel and the subsequent removal of the plated shell so that a self-supporting part or formed article, not a mere coating, is produced. In forming complicated shapes that involve undercuts, the mandrels are made of low melting alloys that can be melted out in a hot oil bath. Electroformed interior surfaces achieve highly reflective mirror finishes without polishing and produce an extremely high degree of density without porosity.

High precision parts are now being electroformed from nickel, copper, iron, silver, lead, tin, cadmium, zinc, cobalt, indium, and chromium.



Instrument float made in one piece with a wall thickness of 0.005" eliminates the need for any welding or soldering operations normally used in joining halves.



Left: Pendulum for gyroscope concentric within 0.001".

Right: Magnetron cathode support made of high-purity electrolytic nickel.

Feel free to send us prints or samples for our engineering comment and quotation. No obligation or charge, of course.

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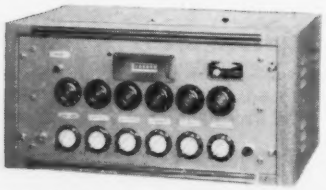

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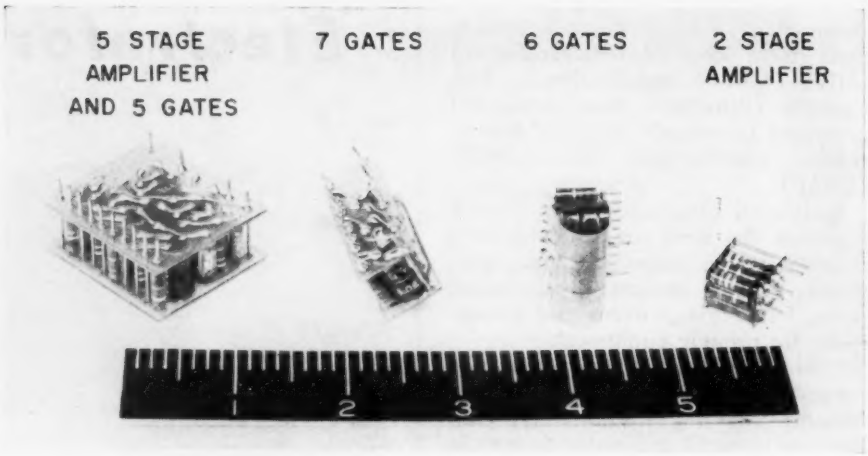

Digital computer sub-modules. Sandwich-type structures obtained by use of two parallel printed circuits with circuit components between, or by one flexible printed circuit folded as in the 6-gate unit. This type of package adapts well to the JETEC-30 transistor case, and to diodes, tantalytic capacitors, and standard types of resistors. When possible, designers use circuit components of similar length—for example, they would use two ½ watt resistors in parallel instead of a single 1-watt unit. The boards, built to a 0.05 inch grid on 0.032 inch thick epoxy glass, are connected together with simple upset pins also used as electrical jumpers. The pins extend to make contact with a mother board, cable board, or socket. One means of connection to a mother board calls for the mounting holes in the mother board to be slightly larger than the pins and for these holes to be located adjacent to the pads. Current construction usually brings the attachment holes through the pads. Locating the attachment holes adjacent to the pads requires that the pins from the module be bent over and soldered to the pad. If the pads are spaced about 1/16 inch from the holes, the module can be removed from the mother board by clipping each of the pins between the holes and the pads or by unsoldering each pin and bending it upright.

CIRCUIT PACKAGING

New Sandwich Design For Printed Circuits

A new packaging technique being applied to low power circuits accelerates the recent trend toward miniaturization, ruggedness, increased space factors, ease of maintainance, and expendability. The technique is exemplified in packaged computer circuits, shown in the illustration, designed by John Strom of RCA Airborne Systems Laboratory, Waltham, Massachusetts.

The ultimate objective for the technique, as explained by Russell Zimmer, Reliability Engineer for the Laboratory, is to redesign circuit components adapting them to sandwich comfigurations to obtain circuit modules as small and interchangeable as present-day vacuum tubes. These units would be factory tested, sealed, and non-repairable in the field. Use of such units would greatly reduce maintenance problems and the need for technical skills in the field.

The designs described in the illustration are adaptations of the ideal concept to present-day components. These designs must allow for repair. The components could be assembled into notches in the edges of the board, rather than into holes, to make disassembly and reassembly easier. The effect of encapsulation can be approached without destroying repairability by dipping the units in resin for that purpose to give them a protective coating and more rigidity but without embedding them.

Mr. Zimmer cited several advantages of the sandwich technique applied to present day components:

- Sandwich modules can be made smaller and lighter
- They are less expensive than double sided boards. Mass produced sandwich modules can be designed for automatic soldering and cleaning
- Inherent reliability of sandwich designs is comparable to that of conventional printed circuits. But actual reliability, which depends on the unit's resistance to shock, vibration, and contamination, should be much better in the new designs, since these factors were major considerations in development of the technique. Dipped in silicon resin, the units are extremely rugged and compact
- Rather surprising space factors have been achieved. Units have been built in which space occupied by the components, not counting the resin, is 85 percent of the module's volume. END

Sealed Slip Ring Assembly Has Varied Applications

This interesting slip ring assembly, originally made for checking strain gauge readings aboard ships, can be adapted for other instrumentation circuits, thermocouple applications, and power circuits. The adaptability is due to the large size of the rings and brushes, which will withstand power circuits. Also, silver-graphite brushes are combined with coin silver rings to render extremely accurate readings. This drum-type assembly has an unusually large inside diameter of 6¾ inches. Other dimensions: overall diameter, 13⅞ inches; over-all length, 10-5/16 inches. *Superior Carbon Products, Inc., Cleveland, Ohio.*

Circle No. 196 on Inquiry Card

Compression-Installed Splicing Connector

A new compression-installed, insulated fixture-type "pigtail" connector designed to splice a wide range of different cable sizes is available from the Omaton Division of Burndy Corporation, Norwalk, Conn. Called BURCAP, the splice is rated for 600 volts for building wire and 1000 volts for fixtures and signs. It is rapidly crimped to the conductors with Burndy installation tooling—plier-type, ratchet, and pneumatic hand tools or pneumatic bench mounted tools.

The link within each splice is tin-plated to resist corrosion and maintain low contact resistance. Insulation jacket is of nylon. Samples, dimensional and test data are available. *Burndy Corporation, Norwalk, Conn.*

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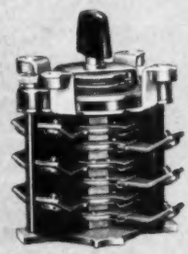
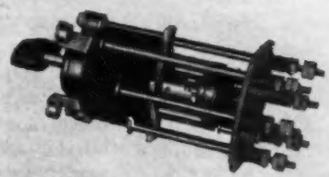


TYPE P, 30A

TYPE A



TANDEM TYPE P, 30-10A

TYPE HT

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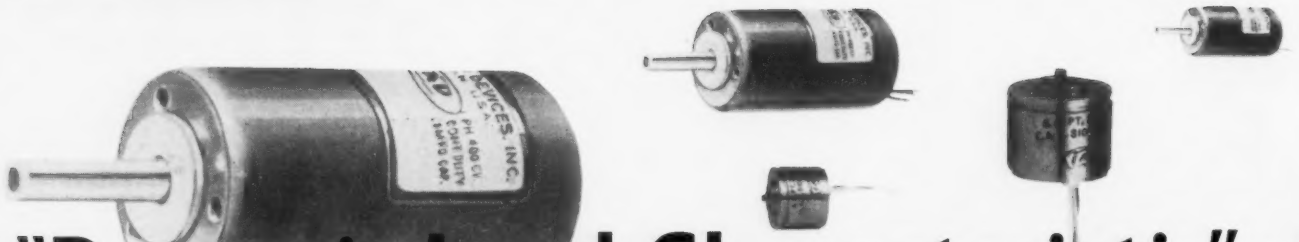

"Dynamic Load Characteristic" of El

DYNAMIC LOAD CHARACTERISTIC *is a new way of representing motor performance, showing, in a single compact curve, available motor power under conditions of high acceleration. With such curves you can quickly compare motors of different no-load speeds, inertias, and power ratings for suitability in specific applications. You can also read from the curve for a selected motor the optimum gear ratio between motor and load.*

In electric motor applications, particularly in servomechanisms, selection of an optimum drive-motor is an important and frequently recurring problem. The problem has special significance in electro-mechanical servomechanisms where the servo motor must be driven by an amplifier. A less than optimum servo motor may require an especially bulky or complex driving amplifier. The amplifier may be required to incorporate stabilization networks to compensate for deficiencies in servo motor dynamic characteristics. Also as a general rule, the requirements for servo motors are more complex than usual motor requirements, and optimum selection is therefore more important.

Let us consider a common general problem in motor selection. The problem will first be viewed in the conventional manner. Then a novel and much more direct solution will be presented.

The problem may be stated as follows: Consider a driven mechanical load that has viscous friction and appreciable inertia. Specifications require that the load be driven by a servo motor through a gear train at some velocity, N_L, with a simultaneous acceleration, A_L. The problem is to select the optimum servo motor and gear ratio. Before proceeding to a solution let us consider the factors involved.

A motor is capable of delivering a certain mechanical power at its shaft. This mechanical power is maximum at a given speed for acceleration equal to zero. Under acceleration, shaft power would be diminished by the power required for acceleration of motor and load inertias.

Because the motor is generally a high-speed low-torque device, while driven loads encountered in practice operate at lower speed with higher torque, a gear train is usually required between motor and load for matching purposes. This gear train functions analogously to the matching transformer commonly employed in electrical circuits. The motor's ability to deliver power to the load is substantially affected by the gear ratio.

In some servomechanisms, where unusually fast, backlash-free performance is required, very high-torque, low-speed motors have been employed directly coupled to the load. This is merely a special application of the dynamic load characteristic to the case of a one-to-one gear reduction. (See article "Direct Drive Eliminates Backlash," on page 24.)

In the general problem the motor is accelerating while driving the load at specified velocity. Available power for the load equals motor power at specified velocity minus the power required for the acceleration of motor plus load (plus effective gear train inertia). Therefore, proper selection of drive motor for an accelerating system is only partially related to the steady-state power capacity of the motor, and is significantly influenced by system inertia. Motor selection becomes rather complex. Is it preferable to choose a high-power high-inertia motor, or a lower power motor with lower inertia, or a high-speed or a low-speed motor? The selection factors are sufficiently complex to warrant mathematical analysis. Some criteria, such as the motor torque-to-inertia ratio (theoretical stall acceleration), serve as rough guides in motor selection. However, they are far from adequate as a general solution.

CONVENTIONAL SOLUTION TO THE PROBLEM

The selection of optimum servo motor and gear ratio for a given load velocity and acceleration is conventionally accomplished by trial and error techniques. A servo motor may be tentatively selected, for example, with adequate mechanical power for driving the load friction component with a considerable safety margin. The safety margin could be considered as the portion of motor output required for acceleration. There are other bases for tentative selection.

Once the motor is selected, it is a simple though tedious matter to verify its suitability. A range of values of gear ratio is assumed. Load power required for the specified velocity and acceleration is readily calculated. For each gear ratio, drive motor acceleration power is likewise calculated. (Motor inertia is known.) Total power (load plus drive motor acceleration power) may be plotted versus gear ratio.

For each gear ratio, motor velocity equals specified load

Electric Motors

Sidney A. Davis,
CONSULTING ELECTRICAL ENGINEER,
Eastern Air Devices, Dover, New Hampshire

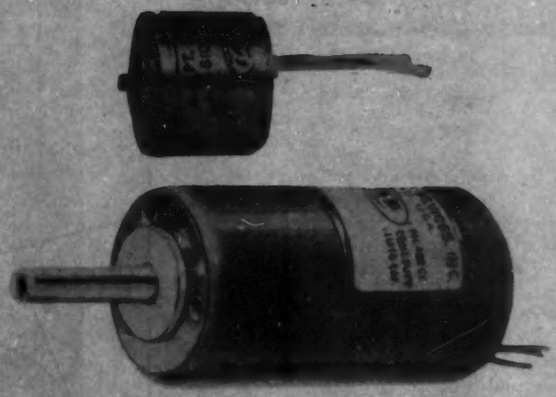

FIG. 1—The dynamic load characteristic illustrates graphically how the small (1 inch O.D.) drive-motor may be better suited to high-inertia loads requiring higher acceleration than the 1¾ inch unit.

velocity divided by the ratio. For zero acceleration, the motor power output is known at each velocity. This, motor power may be plotted versus gear ratio. This curve can be superposed on the power requirement curve described above. Typical curves for this condition are shown in Fig. 2. Figure 2 verifies the suitability of the motor showing its margin of safety, the optimum gear ratio, and the approximate range of suitable gear ratios.

It may be seen from Fig. 2 that selection of an *optimum* gear ratio depends upon establishment of a specific criterion. For example, the ratio may be selected such that motor power divided by required power is maximum, or such that the *difference* is maximum. There are a variety of criteria, however, that tend to give much the same values of gear ratio. The exact criterion is not critical, a point to be remembered in the derivation of the novel design technique described below.

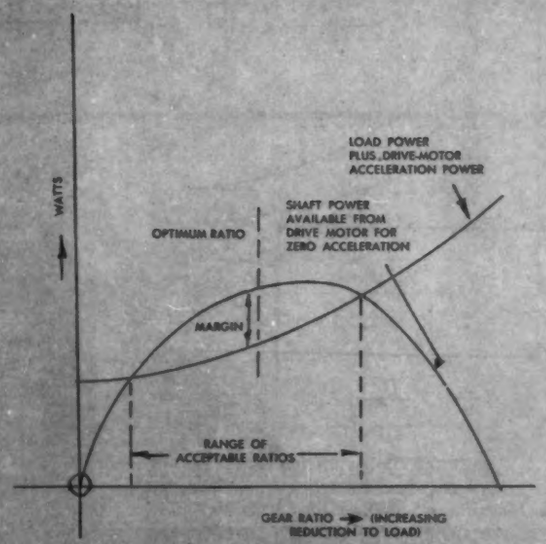
WATTS
LOAD POWER PLUS DRIVE-MOTOR ACCELERATION POWER
SHAFT POWER AVAILABLE FROM DRIVE MOTOR FOR ZERO ACCELERATION
OPTIMUM RATIO
MARGIN
RANGE OF ACCEPTABLE RATIOS
GEAR RATIO → (INCREASING REDUCTION TO LOAD)

FIG. 2—Conventional graphical analysis for gear ratio selection showing range of acceptable ratios, optimum ratio, and margin. If the curves do not intersect, the motor is inadequate.

The above method is general enough for all kinds of motors, and provides a convenient graphical picture. Margins of error and gear ratio tolerances are clearly shown. However, it does not help in initial selection, and as a result, tedious calculations must verify the tentative choice. Further, a series of trials is required to determine which motor of a group is most suitable for an application. Also, for a different load or set of conditions the problem must be repeated in its entirety, the previous motor calculations being no longer useful. The method described below is superior in that it derives a new basic performance characteristic for the motor, which may be conveniently called the *dynamic load characteristic*, or "DLC." Once prepared for a given motor, the dynamic load characteristic is instantly applicable to all problems of the type we are considering, yielding a direct and easily visualized solution. It is especially valuable for comparison of a group of possible motors for suitability for a given application.

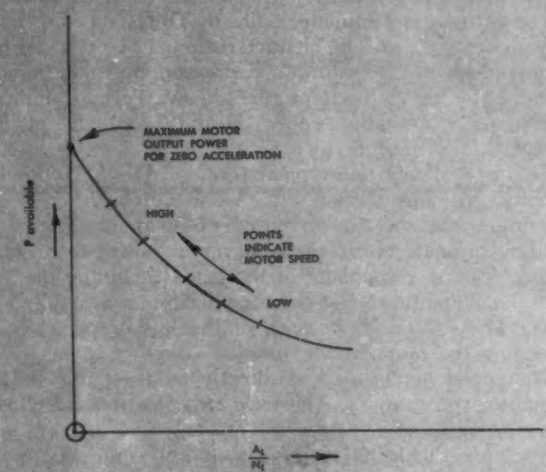

FIG. 3—Typical form of dynamic load characteristic.

DYNAMIC-LOAD-CHARACTERISTIC SOLUTION TO THE PROBLEM

The dynamic load characteristic (DLC) is a type of curve

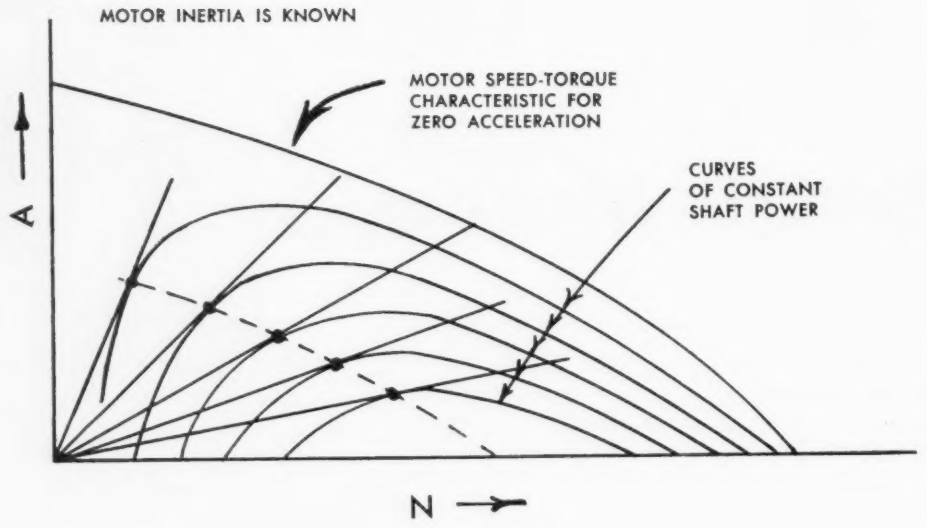

FIG. 5—Acceleration versus speed for various constant values of output shaft power. Curves are derived from conventional motor torque versus speed curve, and rotor moment of inertia. Lines of constant A/N are plotted through the origin tangent to the constant power curves. The dashed line is the locus of the tangency points.

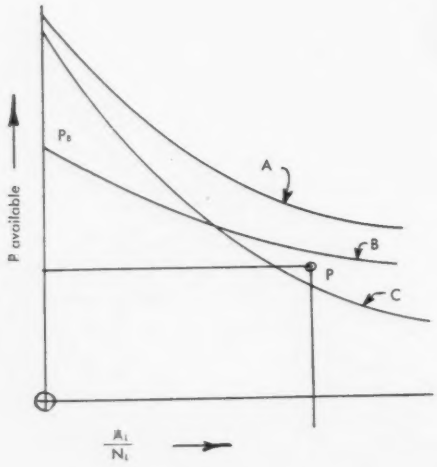

FIG. 4—Optimum choice of motor. For given value of A_L/N_L, and required load power, an operating point, P, is determined. Motor B, having the lowest rated power output, P_B, and lowest inertia, is most suited to load requirements.

that must be determined for each individual motor. Once derived, however, it may be used without modification in a great variety of problems. Designers accustomed to its use will eventually accumulate a file of DLCs for the motors they commonly use. The characteristic may be derived from a motor's speed-versus-torque curve and the rotor moment of inertia by the method described below. Perhaps manufacturers will eventually supply the DLC as part of their formal catalog performance data.

Figure 3 shows the typical form of DLC. If the load velocity, N_L, and acceleration, A_L, are given, then A_L/N_L determines the abscissa of the operating point. The corresponding ordinate reads available motor power to drive the viscous friction component of the load (including the gearing). This quantity is less than the maximum avaiable motor power at $A_L/N_L=O$, because of the loss of power in accelerating the motor's own inertia.

The speed points marked directly on the curve indicate the motor speed at N_L. The ratio of motor to load speed is the gear ratio.

Applying the DLC to the given problem of motor and gear ratio selection for a required load velocity and acceleration results in an immediate direct solution. Furthermore, superposing the DLCs for an assortment of possible motors, Fig. 4, readily determines choice of the best motor.

The derivation of the dynamic load characteristic is based on the following key formula taken from elementary mechanics:

$$T_{shaft} = T_{dev} - JA$$

where

T_{shaft} = available shaft torque at any speed, N, and acceleration, A
T_{dev} = developed motor torque at speed N for A = O
J = motor moment of inertia
A = motor angular acceleration
N = motor speed
JA = torque required for motor acceleration.

Any consistent set of units may be used. To establish the power associated with the individual torque components in the above equation, multiply each term by N.

$$T_{shaft}\,N = P_{shaft} = T_{dev}\,N - JAN$$

T_{dev} N is the conventional motor power output at speed N (at A = O). JAN is the instantaneous power required for accelerating the motor rotor. For simplicity, from here on, let $T_{dev} \equiv T$, and $P_{shaft} \equiv P$. It is possible to plot acceleration versus speed for various constant-shaft powers as shown typically in Fig. 5. Regardless of the gear ratio ultimately selected, the *ratio* of load acceleration to velocity equals the ratio of motor acceleration to velocity. This ratio is therefore immediately known. On the family of motor curves of Fig. 5, lines of constant ratio of acceleration to velocity may be drawn, as indicated, directly through the origin. A good criterion for an optimum operating point would be to select the tangency point between a given straight line and a constant power curve. This would represent maximum available power output from the motor for the given acceleration-to-velocity ratio.

Figure 6 shows the dynamic load characteristic derived directly from Fig. 5. For any given acceleration to velocity ratio, the motor's available power at the tangency point, as well as the speed, may be determined.

The DLC for a given motor may be obtained by straightforward calculation. Examine the equation derived above:

$$P = TN - JAN$$

The motor speed-torque curve shows T versus N. For a series of fixed values of P, A may be calculated as a function of N, yielding a family of curves similar to that of

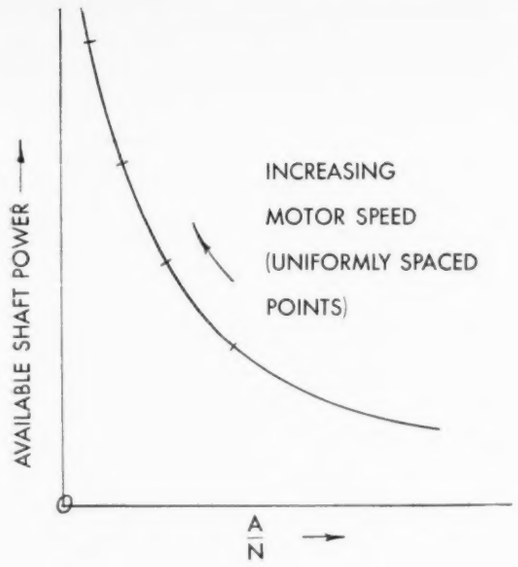

FIG. 6—Dynamic load characteristic for motor of Fig. 5.

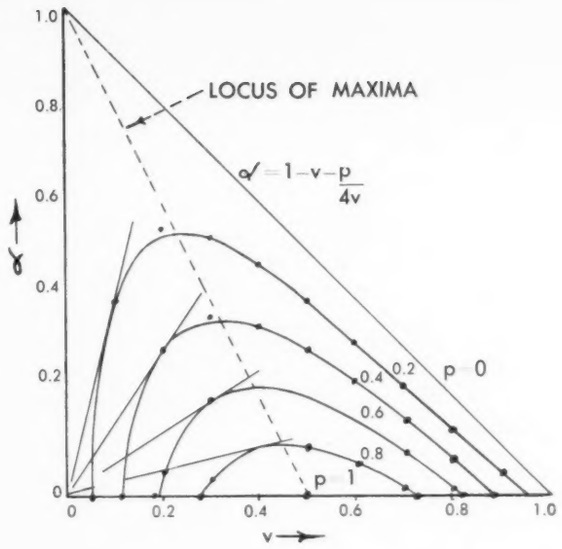

FIG. 7—Dimensionless curves of constant power for servo motor having a straight line speed torque curve.

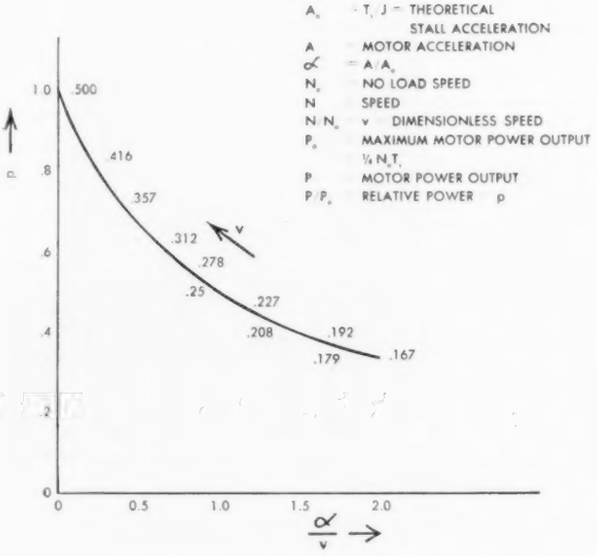

FIG. 8—Dynamic load characteristic for servo motor with straight speed-torque characteristic. Dimensionless nature of curve makes it universally applicable.

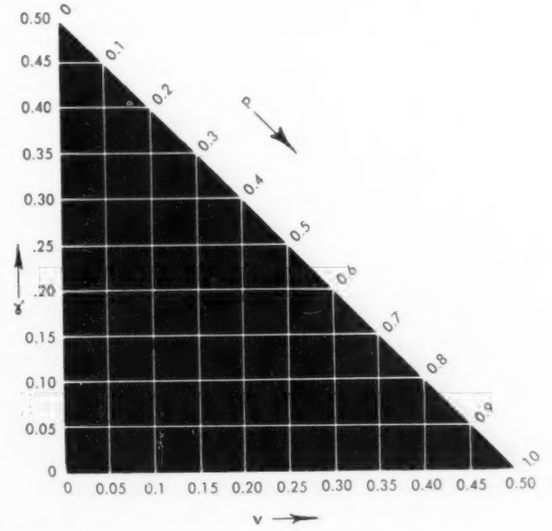

FIG. 9—Nomograph for servo motors having straight-line speed-torque characteristics. If required v and α define a point *within* the triangle, the motor capacity will be adequate.

Fig. 5. By drawing tangents from the origin to the members of the family, you can derive the dynamic load characteristic curve as explained above.

The problem may be somewhat simplified by using dimensionless notation. By a straight-forward substitution of variables, the basic equation becomes

$$P = 4v\ (t - \alpha)$$

where

$P = P/P_o$

$P_o = \frac{1}{4} N_o T_s$

$t = T/T_s$

T_s = stall torque

$v = N/N_o$

N_o = No-load speed

$\alpha = A/A_s$

$A_s = T_s/J$ = theoretical stall acceleration.

The use of dimensionless variables simplifies calculation and contributes to the ease of visualization of the results.

In the case of small servo motors, the speed-torque curve is approximately a straight line connecting T_s and N_o. For this highly special case, the DLC can be described quite simply and generally in dimensionless notation. The equa-

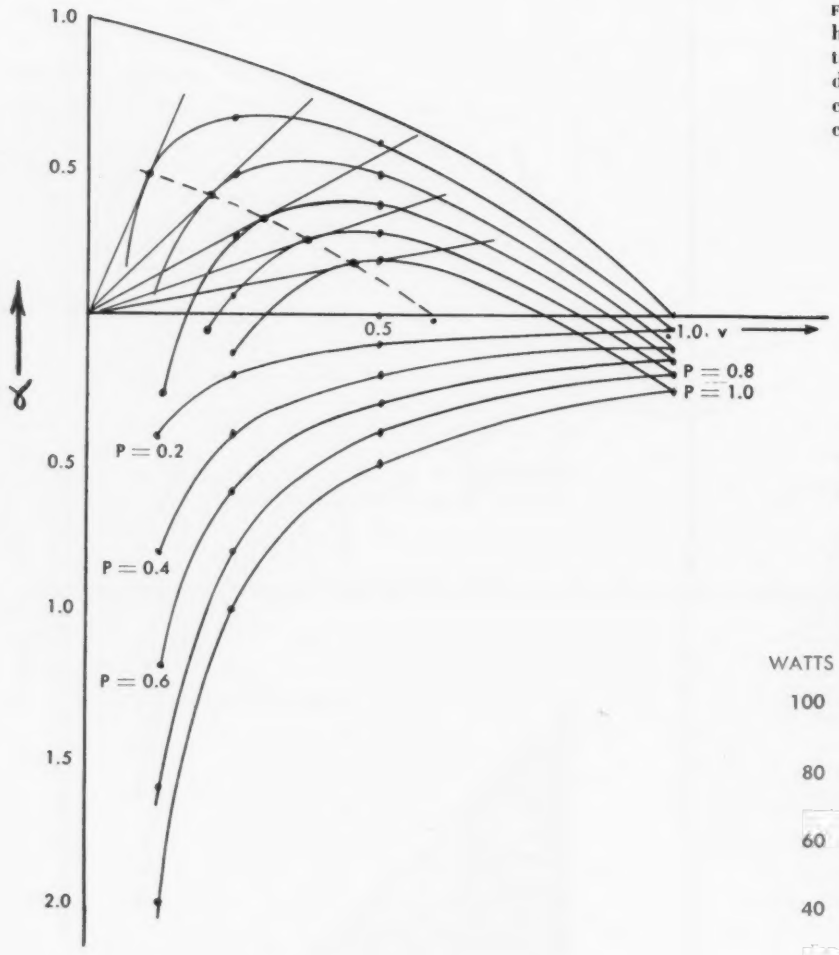

FIG. 10—Derivation of power curves for motor having non-straight speed versus torque characteristic. The locus of tangency points, shown by dashed line, defines points on the DLC. The p= constant curves are quite general, and apply, unchanged, to all motors.

tion of the speed-torque curve is simply $T = 1 - v$. The basic equation becomes

$$p = 4v\ (1 - v - \alpha).$$

This equation may be solved for α:

$$\alpha = 1 - (p/4v) - v.$$

A complete plot of this equation is given in Fig. 7. Figure 8 shows the DLC, which now applies to all motors having straight-line speed-torque characteristics.

Figure 9 shows an intermediate curve applicable only to the straight-line speed-torque case. If a point corresponding to α and v lies within the triangle, the motor will have adequate capacity. The hypotenuse represents the borderline condition. Points on the hypotenuse correspond to available shaft power for the given condition.

Figure 10 is a typical derivation of the power curves for the general case of a curved speed-torque characteristic The curves below the horizontal axis represent (P/4v), and are individually subtracted from the torque curves to give the required family of power curves. The (p/4v) curves are *fixed* and may be used without modification to yield the power curves for any motor. This greatly simplifies the problem of developing the DLC of a given motor.

Figure 11 shows the speed-torque characteristic of a typical high power-output servo motor. The DLC of the same motor is given in Fig. 12. Mixed units are used which are, however, consistent with current practice. Notice the inevitable loss of available motor power with increasing acceleration.

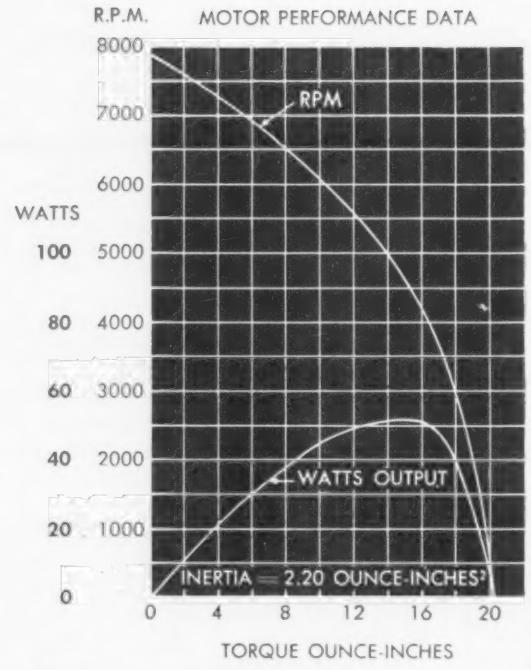

FIG. 11—Motor performance characteristics used in derivation of dynamic load characteristic.

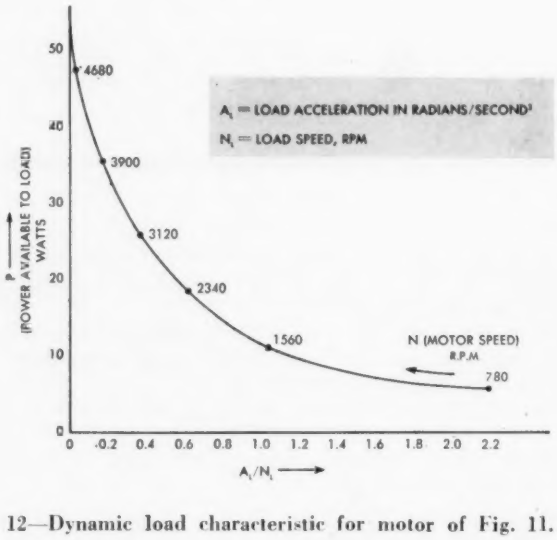

FIG. 12—Dynamic load characteristic for motor of Fig. 11.

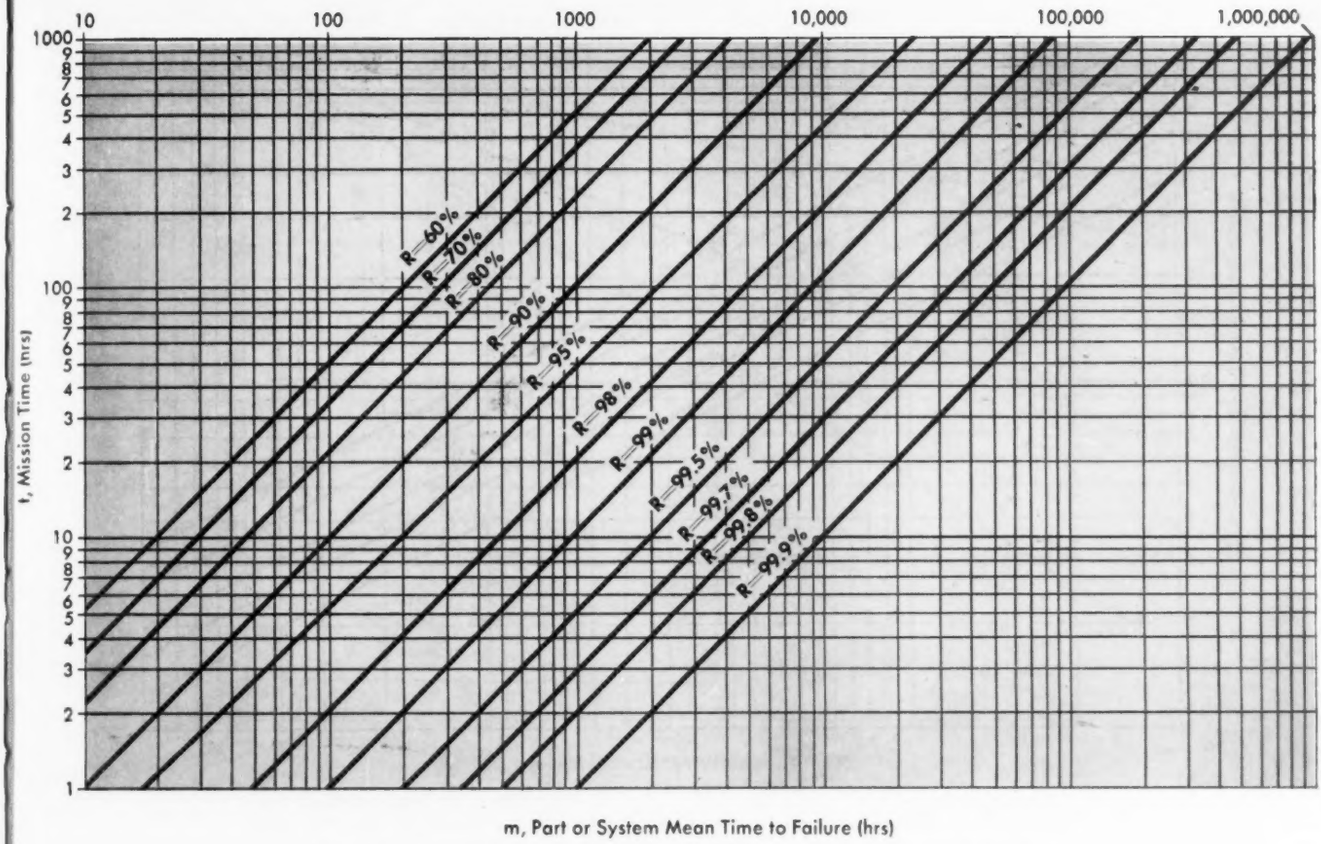

FIG. 1—Curves for converting reliability in terms of mean time to failure, m, to reliability in terms of probability of no failure, R.

Reliability

Estimation, Prediction and Measurement

Here are three simple graphs with which you can estimate, predict and measure the reliability of most of the electronic and electromechanical systems you now have in the design stage.

Seymour Nozick

Seymour Nozick has been specializing in operations analysis and reliability studies of aircraft weapons systems. He holds patents and has published in the fields of storage tubes, dark trace tubes and electronic test equipment. He is joining Hughes Aircraft Co. in Tucson, Arizona.

FROM the time a system is conceived until it is built and used in the field, some idea of its reliability is needed. During the study phase when various configurations are being considered, rough estimates of reliability are sufficient. When the system is blocked out and the parts are chosen, prediction of system reliability based on the best available data on the reliability of the parts is needed. And finally, when the system is built some measure of its reliability is required.

FORMAL ASPECTS OF RELIABILITY

In analyzing systems in terms of formal characteristics affecting reliability, three types of configurations have been identified—chain, redundant and distributed. These configurations can best be described by analogy with three types of actual chain structures.

A chain configuration is like a single chain strand supporting a load. If any link fails the chain fails.

A redundant configuration is like two chain strands supporting a load where either strand is rated to support it alone. This structure is far more reliable than the first. If a link fails causing its chain to fail, the other chain still supports the load.

A distributed configuration is like many chain strands supporting a load where only a fraction of them is required

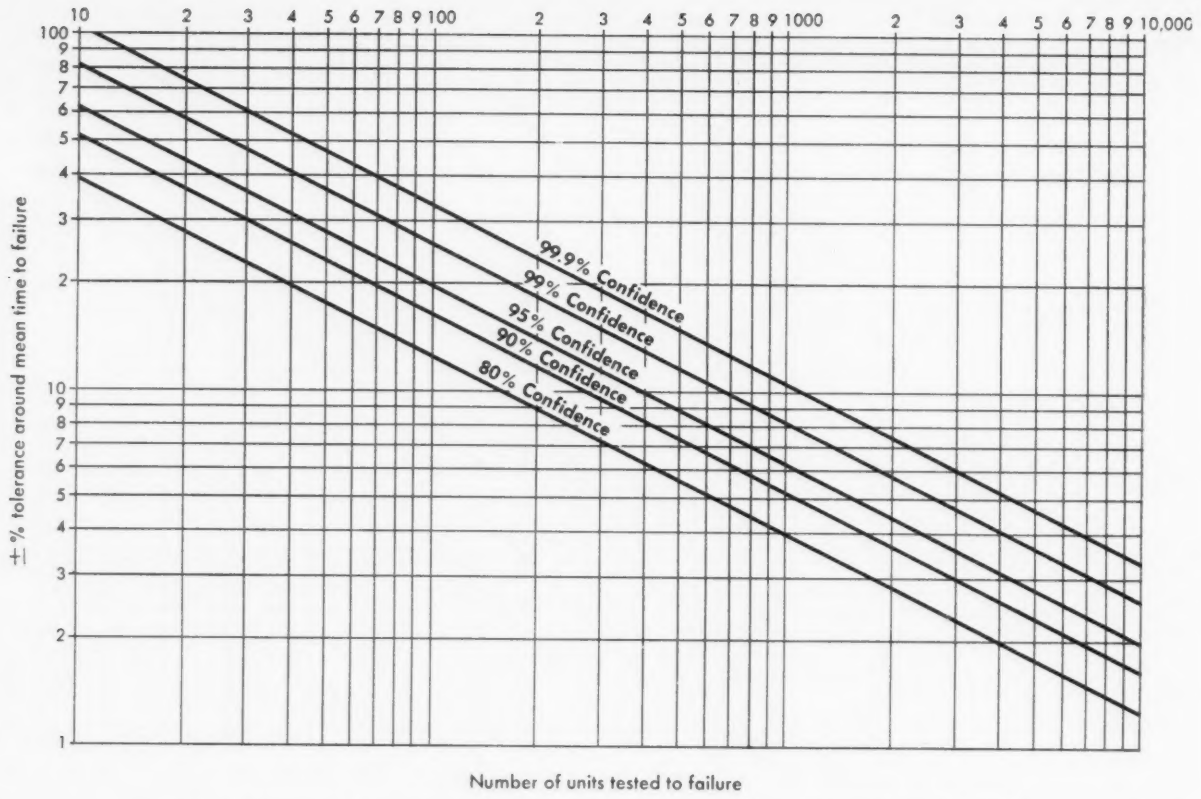

FIG. 2—Curves for estimating reliability of a chain system for various assumed failure rates per stage given the estimated number of stages in the system.

to hold but no one of them can do the job alone. This structure is the most reliable since a number of strands can fail but the load will be held as long as the required fraction of strands remain.

It is apparent from this analogy that chain configurations are building blocks from which the other two are made.

Most electronic and electromechanical systems are chain configurations entirely. Most of the remainder are basically chains in which redundant or distributed configurations replace one or more portions.

A simple check to determine if a given part is a chain element in a given system is to note whether failure of the part would result in failure of the system. Even servos and other feedback devices are chain configurations by this test since failure of any part disables the loop. We will be concerned here with reliability of chain systems only.

MEASURES OF RELIABILITY

The measures of reliability are mean time to failure, failure rate, and probability of no failure. They are interrelated.

Mean time to failure, m, is the mean operating time without failure of a large number of units of a device operated until they fail.

Failure rate, f, is the reciprocal of mean time to failure and represents the percent of failures of the devices per unit time.

Probability of no failure, R, often used as the measure of reliability, is a function of both the failure rate or the mean time to failure and the time the device is to operate without failure, t.

$$R = e^{-t/m} = e^{-ft}$$

This probability says in essence that if we operate a large number of units of a device for time t, R is the probable percent that will be still operable at the end. Accordingly, (1-R) is the probable percent that will have failed during the time t. Fig. 1 is a simple curve for converting m and t to R and vice-versa.

If you are building ground equipment for continuous operation you may want to know how often it would fail —how many down periods per year of operation you could expect. This quantity is given by f or 1/m. If you are designing aircraft equipment to fly two-hour missions you may want to know the percent of flights that would abort during that time because of equipment failure. This quantity is given by (1-R).

In estimating and measuring reliability of chain systems we will use failure rates. The failure rate of a chain system is the sum of the failure rates of the parts. The quantities R and (1-R) for the system can be derived from the reciprocal of its failure rate, 1/f, by using Fig. 1.

RELIABILITY ESTIMATION

Suppose you want to estimate the reliability of equipment being designed given only a rough block diagram of the system and an estimate of the numbers of each part in each block. An estimate of the system failure rate, mean time to failure and probability of no failure for time t can be made based on actual failure rates of typical parts measured by the military in field use. These data take into

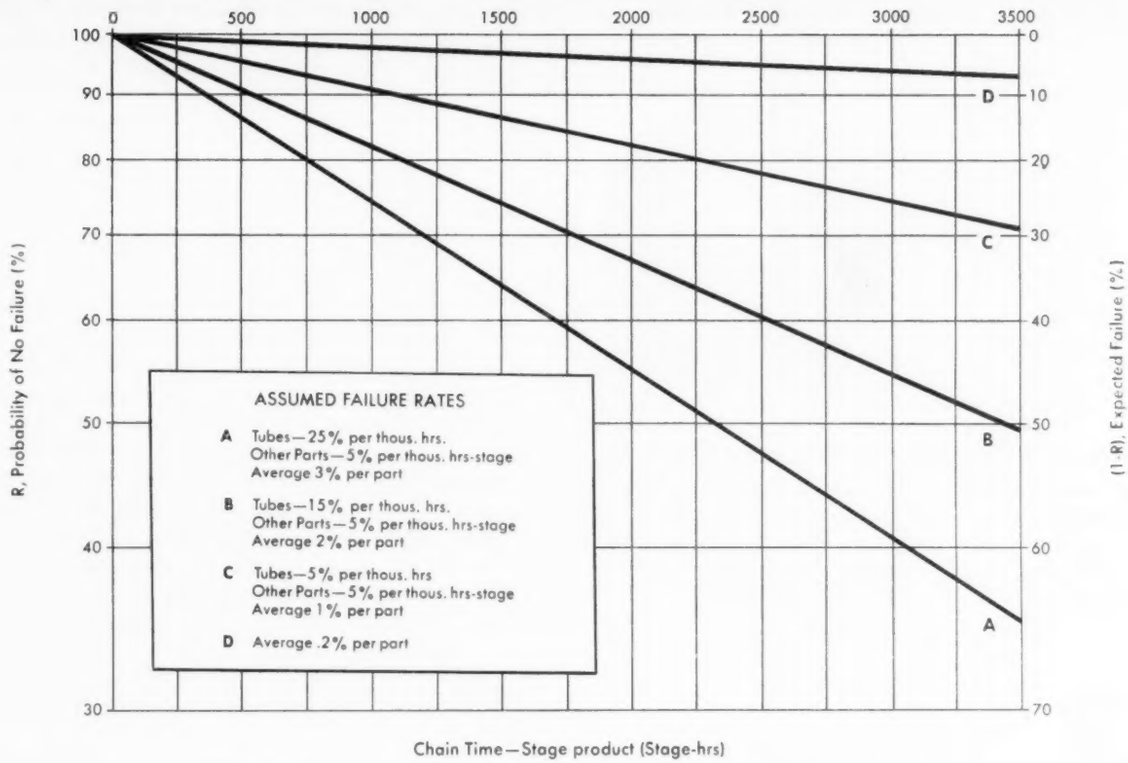

FIG. 3—Curves for determining the confidence that can be placed in reliability test results given the number of units tested to failure.

account the poor maintenance and usage conditions that laboratory tests might not include.

For ground based equipment, failure rates for typical parts, tabulated as a function of percent rated power dissipated and percent rated voltage applied, may be obtained from "A Progress Report on Reliability Measurement and Predictions" by Victor Harris and Max M. Tall, published by the I.R.E. in the "Proceedings of the Second National Symposium on Quality Control and Reliability in Electronics." Table 1 is abstracted from this reference.

The higher failure rates in Table 1 are for operations close to rated. For tubes the lower failure rate is for applied voltage less than 50% of rated and power dissipation less than 25% of rated. For other parts the lower values are for applied voltage and power dissipation less than 25% of rated. The higher values can be used to obtain rough estimates of equipment reliability.

TABLE 1 • FAILURE RATES OF COMPONENTS IN NAVAL EQUIPMENT

Component Type	*Failure Rate Range*
Carbon Resistors	0.1 - 0.8% per 5000 hours
Wire Wound Resistors	0.3 - 2.5% per 5000 hours
Paper Capacitors	0.2 - 2.5% per 5000 hours
Ceramic Feed-thru Capacitors	0.5 - 2.10% per 5000 hours
Ceramic Capacitors	0.2 - 4.0% per 5000 hours
Mica Capacitors	0.15 - 0.35% per 5000 hours
Receiving Tubes	9.0 - 26.0% per 5000 hours

For aircraft equipment entirely different failure rates are obtained as shown in Table 2. These data are abstracted from "Failure Analysis and 'Ballpark' Estimates of Equipment Reliability" by L. D. Smith published in the A.G.E.T. News Bulletin, July 1, 1957.

Suppose you want to estimate the total failure rate of a piece of airborne equipment with 10 tubes, 60 resistors, 40 capacitors, 4 relays, 7 transformers, 5 connectors, 3 switches and 3 blowers. Multiply the number of parts of each type by its failure rate to get the total failure contribution of each part type. For the tubes this product is 250%, for resistors, 30%, and so on. The sum of all the part failure contributions is an educated guess as to the system failure rate. In this example it is 370% per thousand hours or a mean time to failure of about 270 hours.

For ground equipment you may want to know if it is better to use 10 tubes conservatively or 6 tubes operated near capacity. By computing f for both cases from the data in Table 1 you can determine the more reliable.

Early in the design of aircraft electronic equipment when the number of stages is known but the parts breakdown is still undecided, a rough estimate of reliability can nevertheless be obtained.

Figure 2 can be used to estimate the reliability of aircraft equipment in such cases. It gives R and (1-R) di-

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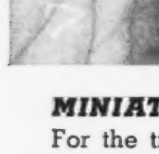

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TABLE 2 • FAILURE RATES OF COMPONENTS IN AIRCRAFT

Component Type	*Failure Rate*
Tubes	25% per 1000 hours
Resistors	0.5% per 1000 hours
Capacitors	0.4% per 1000 hours
Relays	10.0% per 1000 hours
Transformers and Coils	0.2% per 1000 hours
Connectors	1.0% per 1000 hours
Switches	1.2% per 1000 hours
Blowers, Meters	10.0% per 1000 hours

rectly as a function of the product of the number of stages and time in hours for various part failure rates. For example, if we assume average designs of the type used in obtaining the failure rates of Table 2 and plan to build an aircraft system of 500 tubes to be operable for 4 hours, the product of tubes and hours would be 2000. Figure 2 shows that if this equipment is to cause failure in less than 5% of the flights, the designer must use parts with failure rates near those specified in D. The failure rates assumed for A are practical, for B and C, possible, but for D, improbable.

PREDICTING RELIABILITY FROM PARTS

In predicting the reliability of a system when the parts are chosen, you need to know the failure rate for each part type, which you can compute from measurements of their mean time to failure. You can't test the large number of units required in measuring the true mean time, so you select a sample, taking a chance on result. In the language of statistics, the chance that test results are within some tolerance limits about the true mean time to failure is called the confidence.

To measure the mean time to failure of a part type, operate the units of the sample under the conditions they would encounter in use until they fail and compute their mean life. The confidence for this test can be obtained from Fig. 3. For example, suppose 100 tubes were tested to failure and a mean life of 4000 hours were calculated. Figure 3 says you can be 90% sure the true mean life would be within 4000 hours ±12.5%, or 99% sure it would be within 4000 hours ±26%.

Having measured the mean time to failure for each part type, you can then determine the system reliability in terms of f, R or (1-R) as you choose, in the manner described for estimating reliability from the military field failure rates given in Tables 1 and 2. You should be cautioned, however, that use factors may increase the failure rates in the field above those measured in the laboratory by as much as two or three times.

MEASURING EQUIPMENT RELIABILITY

When the system is built and a number of models exist, the final laboratory measure of reliability can be made. The units are life-tested under simulated use conditions, and failure rate or probability of no failure can be computed as was done for parts. The confidence that can be placed in the results, as given by Fig. 3, depends on the number of units tested.

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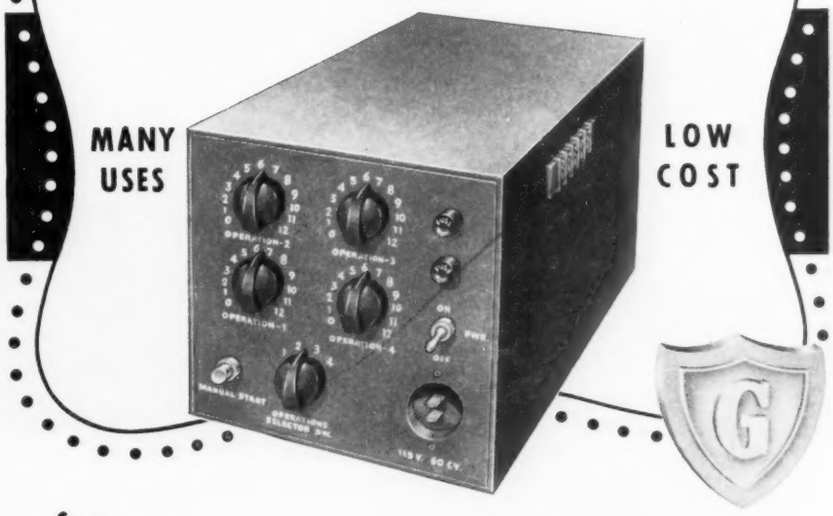

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EMOTIONAL BLOCKS TO

Dr. Maslow is on the Board of Editors of PERSONALITY SYMPOSIA *and* SOCIAL PROBLEMS. *He is co-author of* PRINCIPLES OF ABNORMAL PSYCHOLOGY; *his most recent book, published in 1955, is* MOTIVATION AND PERSONALITY. *As a member of the American Psychological Association, he was elected a fellow in the association's Division of Abnormal and Clinical Psychology and the Division of Personality and Social Psychology. He serves as President of the latter division.*

The problem of the management of creative personnel is fantastically difficult and important. The most creative people are lone wolves, people who are apt to get ground up in an organization, to be afraid of it, to work off in a corner or in an attic by themselves. This, the place of the "lone wolf" in a big organization, is your problem.

It is a little like trying to reconcile the revolutionary with the stable society because creative people are essentially revolutionary in the sense of turning their backs on what already exists, of being dissatisfied with what is now the case.

To summarize in advance, we have found during the last ten years that, primarily, the sources of creativeness of the kind that we're really interested in—the generation of really new ideas—are in the depths of human nature. We don't even have a good vocabulary for it. You can talk about the "unconscious," or about the "real self." But, in any case, it's a *deeper* self. It is deeper in an operational way, in the sense that ore is deep; you struggle to get at it through surface layers.

The source of creativity is a new frontier in the sense that most people don't know about it, and also in another very peculiar sense that has never occurred before in history. *This is something that not only we don't know about but that we're afraid to know about.* There is resistance to knowing about it.

I'm speaking about what I'll call primary creativeness rather than secondary creativeness, the primary creativeness which comes out of the unconscious, the source of new discovery—of real novelty—of ideas which depart from what exists. It is different from what I'll call "secondary

Dr. A. H. Maslow, *Philip Meyers Professor of Psychology and Chairman of the Graduate Committee in Psychology, Brandeis University*

Dr. Maslow was invited by the U. S. Army Engineers at Fort Belvoir, Virginia, to discuss the subject of creativity at one of their Creative Engineering Seminars. Because his "thinking out loud" approach to the problem of creativity in engineering deals with the roots of creativity — as opposed to techniques — we have preserved the flavor of his approach by presenting his talk as it came from the tape. Here, then, is a psychologist's analysis of emotional factors that control your creativity.

OCKS TO CREATIVITY

creativity," the kind of productivity demonstrated in some recent researches of a psychologist by the name of Anne Roe. She was able to demonstrate a very peculiar paradox; to a certain degree many good scientists are what the psychopathologist would call rather rigid, constricted, afraid of their unconscious in the sense that I have mentioned.

And you may come to a peculiar conclusion that I've come to. I now think in terms of two kinds of science and two kinds of technology. Science can be defined, if you want to, as a technique whereby uncreative people can create and discover by working along with a lot of other people, by standing upon the shoulders of people who have come before them, by being cautious and careful. Now, that I'll call secondary creativeness and secondary science.

However, I can be of most use to you by laying bare the primary creativeness which comes out of unconscious and which I have found in the specially creative people I have selected to study carefully. This kind of primary creativeness is very probably a heritage of every human being. It is a common and universal kind of thing. It is the kind of creativeness that any healthy child had and which is then lost by most people as they grow up. It is universal in another sense, that if you dig in a psychotherapeutic way, into the unconscious layers of the person, you find it there.

I shall give you only one example you have probably all experienced yourselves. You know that in our dreams, we can be more creative than we are in waking life, more clever, wittier, bolder, more original. With the lid taken off, with the controls taken off, the repressions and defenses taken off, we find generally more creativeness than appears to the naked eye.

I think I can be of service in this area by helping you to become as aware as possible of these unconscious processes, of that the psychoanalyst calls "primary processes" and "secondary processes." There is no good statement of this available in any literature. It is a tough job to try to be orderly about disorderliness and rational about irrationality but we've got to do it.

These primary processes, these unconscious processes of cognizing, of perceiving the world and of thinking, are very, very different from the laws of common sense, good logic, of what the psychoanalyst calls the "secondary processes" in which we are logical, sensible and realistic. When "secondary processes" are walled off from the primary processes, then both the primary and secondary processes suffer.

At the extreme, the walling off of or the complete splitting off of logic, common sense, and rationality from the deeper layers of the personality produce the compulsive-obsessive person, the compulsively rational person, the one who can't live in the world of emotion at all, who doesn't know whether he's fallen in love or not because love is illogical, who can't even permit himself to laugh very frequently because laughing isn't logical. When this is walled off, when the person is split, then you've got a diseased rationality and also diseased primary processes. These secondary processes, walled off and dichotomized, can be considered largely an organization generated by fears and by frustration, a system of defenses, repressions and controls, of appeasement, and cunning underhanded negotiations with a frustrating and dangerous physical and social world which is the only source of gratification of needs and which makes us pay very dearly for whatever gratifications we get from it. Such a sick conscious, or ego, or conscious self becomes aware of and then lives only by what it perceives to be the laws of nature and of society. This means a kind of blindness. The compulsive obsessive person not only loses much of the pleasures of living, but also he becomes cognitively blind to much of himself, much in

other people, and even in nature. There is much he is blind to in nature even as a scientist. It is true that such people can get things done, but we must ask in the first place, as psychologists always ask, *At what cost* to himself? (because he's not a happy person) and secondly, we also ask about this business of getting things done, *Which things?* And are they worthy of doing?

The best case I ever ran across of a compulsive-obsessive man was one of my old professors. He was a man who very characteristically saved things. He had all the newspapers that he had ever read, bound by weeks. I think each week was bound with a little red string, and then all the papers of the month would be put together and tied with a yellow string. His wife told me that he had a regular breakfast every day. Monday was orange juice, Tuesday was oatmeal, and Wednesday was prunes, and so on, and God help her if there were prunes on Monday. He saved his old razor blades, packaged nicely with labels on them. When he first came into his laboratory, he labeled everything. I remember his spending hours trying to get a label on a little probe of the sort that didn't have any space for a label at all. And once I turned up the lid of the piano in his laboratory and there was a label on it, identifying it as "Piano." Well, this kind of man is in real trouble. He is himself extremely unhappy. The kind of things that this fellow did are pertinent to the question I raised above. These people get things done but which things do they get done! Are they worth-while things? Sometimes they are and sometimes they are not.

We know also unfortunately that many of our scientists are of this type. It happens that, in this kind of work, such a poking character can be very useful. Such a man can spend twelve years in poking at, let's say, the microdissection of the nucleus of a one-celled animal. It takes that kind of patience, persistence, stubbornness and need-to-know that all people have. Society can often use that sort of person.

Primary processes then in this dichotomized, walled-off, feared sense, is a sickness. But it *needn't* be a sickness. Deep down, we look at the world through the eyes of wishes and fears and gratifications. Perhaps it will help you if you think of the way in which a really young child looks at the world, looks at itself and at others. It is logical in the sense of having no negative, no contradictions, no separate identities, no opposites, no mutual exclusions. Aristotle doesn't exist for the primary processes. It is independent of control, taboos, discipline, inhibitions, delays, planning, calculations of possibility or impossibility. It has nothing to do with time and space or with sequence, casualty, order, or with the laws of the physical world. This is a world quite other than the physical world. When it is placed under the necessity of disguising itself from conscious awareness to make things less threatening, it can condense several objects into one as in a dream. It can displace emotions from their true objects to other harmless ones. It can obscure by symbolizing. It can be omnipotent, ubiquitous, omniscient.

Remember your dreams, now. Everything I've said holds for the dream. It has nothing to do with action for it can make things come to pass without doing or without acting, simply by fantasy. For most people it is preverbal, very concrete, closer to raw experiencing and usually visual. It is prevaluational, premoral, pre-ethical, pre-cultural, prior to good and evil. Now, in most civilized people just because it has been walled off by dichotomizing, it tends to be childish, immature, crazy, dangerous, frightening. Remember I've given you an example of the person who has completely suppressed the primary processes, completely walled off the unconscious. Such a person is a sick man in the particular way which I have described. The person in whom the secondary processes of control, reason, order, logic, have completely crumbled is a schizophrenic. He's a very sick man, too.

I think you can see where I'm leading you. The healthy person who creates has somehow managed a fusion and a synthesis of both primary and secondary processes; both conscious and unconscious; both of deeper self and of conscious self. And he manages to do this gracefully and fruitfully. Certainly it is possible to do even though it is not very common. It is certainly possible to help this process along by psychotherapy; deeper and longer psychotherapy can be even better.

What happens in this fusion is that both the primary processes and the secondary processes, partaking of each other, change in character. The unconscious doesn't become frightening any more. This is the person who can live with his unconscious, live with, let's say, his childishness, his fantasy, his imagination, his wish fulfillment, his femininity, his poetic quality, his crazy quality. He is the person, as one psychoanalyst said in a nice phrase, "who can regress in the service of ego." This is *voluntary* regression. This person has that kind of creativeness at his disposal, readily available.

The compulsive-obsessive kind of man that I mentioned earlier, in the extreme instance, can't play. He can't let go. Such a man tends to avoid parties for instance because he's so sensible and you're supposed to be a little silly at a party. Such a man is afraid to get a little tight because his controls loosen up and for him this is a great danger. He has to be in control all the time. Such a person will probably make a horrible subject for hypnosis. He will probably get frightened by being anesthetized, or by any other loss of full consciousness. These are people who try to be dignified, orderly, conscious, rational at a party where you are not supposed to be. Do you see what I mean when I say that the person who is comfortable enough with his unconscious is able to let go that much anyhow, to be a little crazy in this party sense, to be silly, to play along with a gag and to enjoy it—to enjoy being nutty for a little while anyhow "in the service of the ego." This is like a conscious, voluntary regression—instead of trying to be dignified and controlled at all times.

Perhaps I can now say something more about this openness to the unconscious. This whole business of psychotherapy, of self-therapy, of self-knowledge is a difficult process because, as things stand now for most of us, the conscious and the unconscious are walled off from each other. How do you get these two worlds, the psychic world and the world of reality to be comfortable with each other? In general, the process of psychotherapy is a matter of slow confrontation, bit by bit with the help of a technician,

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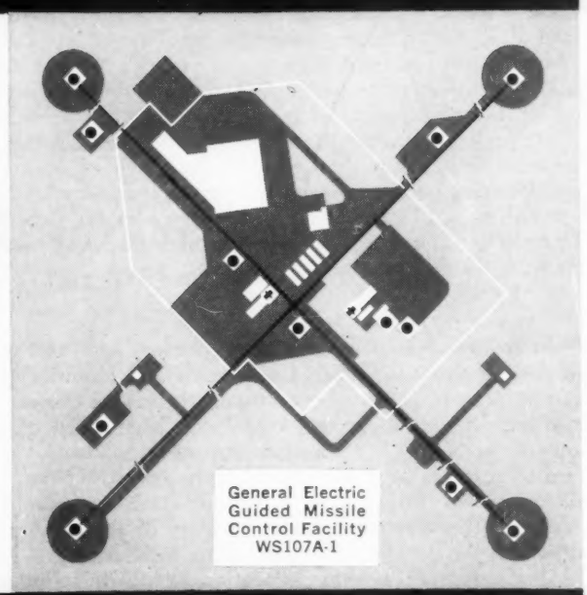

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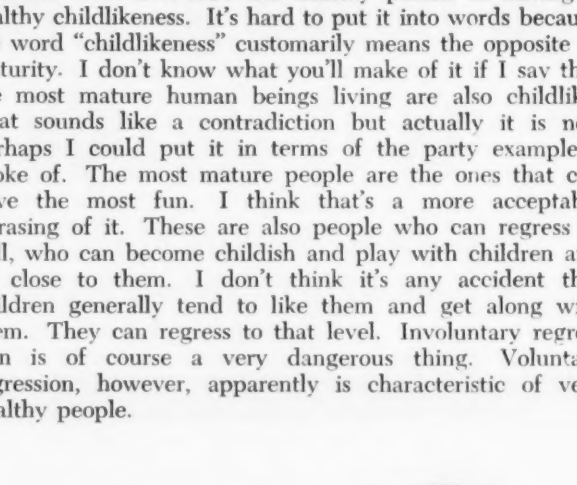
with the uppermost layers of the unconscious. They are exposed and tolerated and assimilated and turn out to be not so dangerous after all, not so horrible. Then comes the next layer, and then the next, in this same process of getting a person to face something which he is terribly afraid of, and then finding when he does face it, that there was nothing to be afraid of in the first place. He has been afraid of it because he has been looking at it through the eyes of the child that he used to be. This is childish misinterpretation. What the child was afraid of and therefore repressed was pushed beyond the reach of common sense learning and experience and growing up, and it has to stay there until it's dragged out by some special process. The conscious must become strong enough to dare friendliness with the enemy.

Chronologically, our knowledge of primary processes was derived first from studies of dreams and fantasies and neurotic processes, and later of psychotic, insane processes. Only little by little has this knowledge been freed of its taint of pathology, of irrationality, of immaturity, and primitiveness, in the bad sense. Only recently have we become aware, fully aware, from our studies of healthy people, of the creative process, of play, of aesthetic perception, of the meaning of healthy love, of healthy growing and becoming, of healthy education, that every human being is both poet and engineer, both rational and nonrational, both child and adult, both masculine and feminine, both in the psychic world and in the world of nature. Only slowly have we learned what we lose by trying daily to be *only* and *purely* rational, *only* "scientific," *only* logical, *only* sensible, *only* practical *only* responsible. Only now are we becoming quite sure that the integrated person, the fully evolved human, the fully-matured person, must be available to himself at both these levels, simultaneously. Certainly it is now obsolete to stigmatize this unconscious side of human nature as sick rather than healthy. That's the way Freud thought of it originally but we are learning different now. We are learning that complete health means being available to yourself at all levels. We can no longer call this side "evil" rather than "good," lower rather than higher, selfish rather than unselfish, beastly rather than human. Throughout human history and especially the history of Western civilization and more especially the history of Christianity has there tended to be this dichotomy, an illegitimate "either/or" in which by the very process of splitting and dichotomizing we create a sick "either" and a sick "or," that is to say a sick conscious and a sick unconscious, a sick rationality, and sick impulses. Rationality can be quite sick, as you can see on television very quickly these days with all the quiz programs. I heard of one poor fellow, a specialist in ancient history making an awful lot of money, who told somebody that he had gotten this way simply by memorizing the whole Cambridge Ancient History. He started with page one and went on right thru and now he knows every date and name in it. The poor guy! There is a story by O. Henry about a man who decided that since the encyclopedia encompasses all knowledge he wouldn't bother going to school, but would simply memorize the encyclopedia. He started with the A's worked his way on thru the B's, C's and so on. Now that's a sick rationality.

Once we transcend and resolve this dichotomy, once we can put these together into the unity in which they are originally, for instance, in the healthy child, in the healthy adult, or in specially creative people, then we can recognize that the dichotomizing or the splitting is itself a pathological process. And then it becomes possible for your civil war to end.

This is precisely what happens in people that I call self-actualizing. The simplest way to describe them is as psychologically healthy people. It is *exactly* what we find in such people. When we pick out from the population the healthiest one percent or fraction of one percent, then these people have in the course of their lifetime, sometimes with the benefit of therapy, sometimes without, been able to put together these two worlds and to live comfortably in both of them. I've described the healthy person as having a healthy childlikeness. It's hard to put it into words because the word "childlikeness" customarily means the opposite of maturity. I don't know what you'll make of it if I say that the most mature human beings living are also childlike. That sounds like a contradiction but actually it is not. Perhaps I could put it in terms of the party example I spoke of. The most mature people are the ones that can have the most fun. I think that's a more acceptable phrasing of it. These are also people who can regress at will, who can become childish and play with children and be close to them. I don't think it's any accident that children generally tend to like them and get along with them. They can regress to that level. Involuntary regression is of course a very dangerous thing. Voluntary regression, however, apparently is characteristic of very healthy people.



The only way I know for making this fusion within the person is psychotherapy. And this is certainly not a practicable or even a welcome suggestion. There are possibilities, of course, of self-analysis and self-therapy. Any technique which will increase self-knowledge in depth should in principle increase one's creativity by making available to oneself these sources of fantasy, play with ideas, being able to sail right out of the world and off the earth; getting away from common sense. Common sense means living in the world as it is today, but creative people are people who don't want the world as it is today but want to make another world. And to be able to do that, they have to be able to sail right off the surface of the earth, to imagine, to fantasy, and even to be crazy and nutty. The suggestion I have to make, the practical suggestion for you people who manage creative personnel, is simply to watch out for such people as they already exist and then to pluck them out and hang on to them.

I think I was able to be of service to one company by making this recommendation. I tried to describe to them what these primary-creative people are like. They are precisely the ones that make trouble in an organization, usually. They tend to be unconventional, a little bit queer, unrealistic; they are often called undisciplined, sometimes inexact, "unscientific," that is, by a specific definition of science. Their more compulsive colleagues call them irresponsible, wild, crazy, speculative, uncritical, irregular, emotional, and so on. This sounds like a description of a bum or a Bohemian or an eccentric. And it should be stressed, I suppose, that in the early stages of creativeness, you've got to be a bum, and you've got to be a Bohemian, you've got to be crazy.

The "brainstorming" technique may help us toward a recipe for being creative. People who have already successfully been creative let themselves be like this in the early stages of thinking. They let themselves be completely uncritical. They allow all sorts of wild ideas to come into their heads. And in great bursts of emotion and enthusiasm, they may scribble out the poem or the formula or the mathematical solution or work up the theory, or design the experiment. Then, and only then, do they become secondary, become more rational, more controlled and more critical. If you try to be rational and controlled and orderly in this first stage of the process, you'll never get to it. Now the brainstorming technique, as I remember it, consisted in just this—in not being critical, letting yourself play with ideas, free association, letting them come out on the table in profusion, and then only later on tossing away those ideas which are bad or useless and retaining the ones which are good. If you are afraid of making this kind of crazy mistake then you'll never get any of the bright ideas either.

Of course this kind of Bohemian business is not necessarily uniform or continued. I am talking about people who are able to be like that *when they want to be*. These same people can afterwards put on their caps and gowns and become grown up, rational, sensible, orderly and so on, and examine with a critical eye what they produced in a great burst of enthusiasm and creative fervor. Then they can say sometimes, "It felt wonderful while it was being born, but it's no good," and toss it away. A truly integrated person can be both secondary and primary, both childish and mature. He can regress and then come back to reality, becoming then more controlled and critical in his responses.

I mention that this was of use to one company or at least to this one person in the company who was in charge of creative personnel, because it was precisely this sort of person he'd been firing. He had laid very great stress on taking orders well and on being well-adjusted to the organization.

I don't know how an organization manager is going to work these things out. I don't know what would happen to morale. This is not my problem. I don't know how it would be possible to use such characters in the middle of an organization which has to do the orderly work that ensues upon the idea. An idea is just the beginning in a very complex process of working out. That's a problem that we'll be working out in this country more than any other place on the face of the earth, I guess, during the next decade or so. We've got to face it. Huge sums of money are now going into research and development. The management of creative personnel becomes a new problem.

However, I have no doubt that the standard of practice which has worked well in large organizations absolutely needs modification and revision of some sort. We'll have to find some way of permitting people to be individualistic in an organization. I don't know how it will be done. I think it will have to be a practical kind of working out,

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just simply trying out this and trying out that and trying out the other, and finally coming to kind of an empirical conclusion. I would say that it would be a help to be able to spot these as characteristics, not only of craziness but also of creativeness. By the way I don't want to put in a good recommendation for everybody who behaves like this. Some of them actually *are* crazy. Now we've got to learn to distinguish. It's a question of learning to respect or at least to look with an open eye on people of this sort and trying somehow to fit them into society.

You will find them, I think, more in the academic situation than you will in large organizations or large corporations. They tend to be more comfortable there because they're permitted to be as crazy as they like. Everyone expects professors to be crazy, anyhow, and it doesn't make much difference to anyone. They're not beholden to anyone else except for their teaching, perhaps. But the professor has time enough ordinarily to go off into his attic or his basement and dream up all sorts of things, whether they are practical or not.

In an organization you've got to give out, ordinarily. I don't know how you can put these necessities together in your situation. That's your problem. It's like a story I heard recently. Two psychoanalysts met each other at a party. One analyst walked up to the other analyst and slapped him in the face without any warning. The analyst who was slapped looked startled for a moment and then shrugged his shoulder and said, "That's his problem." END

STAFF COLUMNIST

Renato Contini
Research Coordinator of
New York University, New York, N.Y.

HUMAN FACTORS IN DESIGN

I stated in a previous column, that the design engineer when confronted with a design problem in which the human element is involved, in whatever capacity—should draw upon the basic information provided by the life sciences. In the application of this knowledge to the study of human performance, two comparatively new disciplines have emerged—*Bio-mechanics* and *Engineering Psychology* or *Human Engineering*. The former concerns itself principally with the physical performance of man; the latter considers man in a system. In this issue, I shall elaborate on the field of Bio-mechanics.

Bio-mechanics has been defined as "the science which investigates the effect of internal and external forces on human and animal bodies in movement and at rest." Internal forces are generated in the muscles and transmitted to external objects—wheels, levers, controls, and so on, by the limbs which act as elastic transmission systems. External forces on the body system are gravity, inertia, ground reactions and the resistance of the medium through which the movement occurs.

As in other fields of mechanics, bio-mechanics may be divided into bio-statics and bio-dynamics. Bio-static analysis of an activity is essentially an analysis of body positions. In this the external forces, their magnitude, direction and points of application on the body are considered. The points of support of the body, their shape and size, the way in which stable equilibrium may be maintained, how the body segments act as levers of various classes, the fulcrum points, the points of load application (muscle or tendon attachment) are of concern in a bio-static analysis.

Bio-dynamics may be sub-divided into bio-kinematics and bio-kinetics. Kinematic analysis is essentially the study of the time-space relationships of movement. The shape, size and position of the motion path in a plane or in space may be studied from the point of view of efficiency as was done by Gilbreth—or for the purpose of space requirements as is done in many military design situations.

Kinetic analysis studies how the action of a set of forces, internal and external, influences the motion of a given body segment or system of body segments. The active forces and moments may be determined from the space time patterns of the movement (from which linear and angular velocity and acceleration may be computed), from the mass of the individual body segments (which may be measured or computed) and from dynamic weight measurements. Such an analysis will determine the amount of external stress imposed on the body in a work situation and can lead to the design of the task which will result in the minimum external stress for a given end result.

Bio-mechanics uses not only the findings of theoretical mechanics, but also draws from anthropometry the physical dimensions of body segments; from anatomy, the essential elements of body structure, the axes of motion, the points of attachment of tendons and muscles; from physiology, an understanding of the neuro-muscular system and an application of the sources of internal energy and the metabolism of activity; and from psycho-physiology, an awareness of the psycho-motor patterns and their influence on coordination of movements.

Till recently, the tools and techniques for the bio-mechanical study of activity were principally photogrammetric. Various systems for the continuous recording of movement in space and time were used. The refinement of electrical strain measuring devices (fine wire resistance gauges, capacitor gauges, and so on) have made new recording equipment possible—dynamic weight recording devices, accelerometers, pressure measuring equipment.

Applied bio-mechanics has found its greatest use in improving movement and position in industrial operations, in sports activities, and more recently in medicine (in the study of prosthetic and orthopedic devices) and in military equipment design.

For those who may want further information on the subject of bio-mechanics and its history and development through the years, a partial bibliography may be found in the article on Bio-mechanics written by the author in conjunction with Rudolf Drillis, for the February 1954 issue (Vol. 7, No. 2) of Applied Mechanics Reviews.

TRANSLATIONS

Of Selected
USSR Technical Reports
Andrew R. MacAndrew
Foreign Editor

Use of Code Rings in Remote Control

A. N. Radchenko reporting in *Avtomatica i Telemekhanika* (Automation and Remote Control), August 1957, on principles of ring coding says that use of code rings in telemetering and remote control systems simplifies both coding and decoding equipment. Circular arrangement of the code series gives a more compact and reliable method of conveying code information.

He reports that arrangement of code cells in a circular ring allows complete coverage of all codes without repetition of any given one. This arrangement permits the use of a commutator switching system with direct synchronization by a pulse generator.

The use of code or digit method of transmission and reception, he says, makes it possible to solve a wide range of problems with minimum complexity. Full satisfaction can be obtained from the equipment in regard to range of action, precision, adaptability, automation of control and high-speed action. A good illustration of the trend in pulse-code methods is the modern electronic digit machines which are also used for processing non-mathematical information. In telemechanics, the most important qualities are resistance to interference and precision—especially in remote control. In this respect, code methods of transmission are superior to all other methods.

Code methods in telemechanics are often restricted by the complexity of coding and decoding equipment. Code rings simplify the coding arrangements.

In most coding devices, the codes are formed by means of memorizing devices which reproduce all the utilized codes. Such devices are selector plates of coding tubes, magnetic matrix nets, the rectifier matrices, optical masks and ciphers, etc. The number of elements in these devices is the product of the number of codes by the number of digits each code contains. In general, the number of elements in these arrangements is equal to the number of signs required for the registration of the table of the code used. Thus, in order to present 32 five-digit binary codes, 160 elements are needed; to present five-digit varying symbol codes of 3 symbols, 240 elements are needed. As such, the total number of elements required is the main obstacle to simplification of the apparatus. Code rings offer a simplified way of representation of the total of the n-digit codes. Mr. Radchenko applies the term code ring to a special circular arrangement aimed at a more compact representation of a code series. The rule governing the arrangement is: within the boundaries of the cycle, the series contains no sections with repetition of the n-digit pulse combinations and the sum of all possible selected n-digit sections—including the mutually overlapping ones—gives all the possible code combinations. Thus, the ring contains all possible codes and each code is contained therein only once.

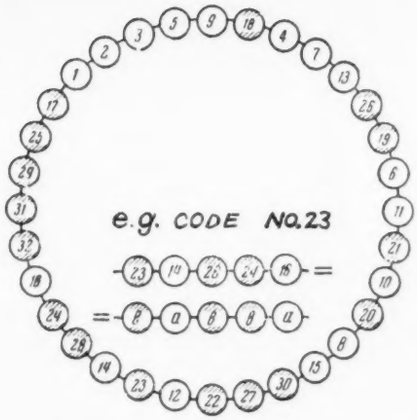


Fig. 1—The code ring of binary five-digit codes.
a. The code table
b. The code ring. The white circles indicate the "a" symbols, the lined circles indicate the "b" symbols.

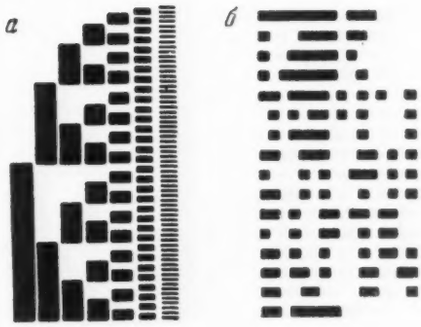


Fig. 2—The configuration of the selector plate of the coordination tube.
a. Conventional representation of 128 codes
b. Ring representation of 256 codes.

Figure 1 illustrates the way to represent a series of binary five-digit codes in the form of a ring. You can compare the figures in the code table (Fig. 1a and those designating the digits of the code ring, Fig. 1b) taking the elements in the ring clockwise. Code No. 24 would be 24, 18, 32, 31, 29 or babbb.

Here one sees where the representation of the code series in the form of a ring makes it possible to represent 32x5 digits with 32 elements. The reduction of the number of elements thus obtained is a multiple of the number of code digits *n*. The number of elements in the ring is always equal to the number of codes, regardless of the number of digits that the code may contain. Thus the more digits the code contains, the more advantageous will be the ring representation of the code sets.

To compare the efficiency of the method, Fig. 2 shows some plates of a coordinating matrix for 128 codes in the conventional representation and for 256 codes in the ring representation. Despite the fact that in 2b the set of codes is twice that of 2a, the selector plate in 2b has a much simpler configuration.

In order to obtain the representation of the codes by the type of plate in 2b, a TV-type of development utilizing a synchronized beam sweep is required. The code is formed as exposure to the beam takes place over one of the n-element sectors of the sector plate. The code can be fitted either in one line or two contingent lines.

Mr. Radchenko says that the ring form is suitable for the representation of complete code sets of the codes known at present, whatever their number of digits and whatever the number of symbols used. That code rings for the various laws governing code sets exist is proved in the general case provided the following two conditions are satisfied:

- Condition 1: The identical left- and right-hand digit combinations within individual codes of the total code set must occur the same number of times.

If the left-hand, n-1, elements of a code form a combination identical with the right-hand combination of another code, these codes are termed *intersecting* codes.

- Condition 2: It should be impossible to divide the code set into two parts such that the first part would contain no single code intersecting with a code of the second part.

Both these conditions are fulfilled in the purely positional codes. The

Fig. 3—Code ring of binary digit position code.
$k=2,\ n=6,\ m=k^n=64$

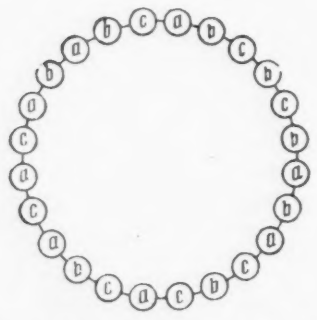


Fig. 4—Code ring of varying symbol codes.
$k=3,\ n=4,\ m=k(k-1)^{n-1}=24$

Fig. 5—Code ring of boundary arrangements.
$A_k^{k-1}=k!,\ k=4,\ m=k!=24$

correctness of these conditions is demonstrated similarly in the case of code sets governed by different laws. On this basis we can demonstrate the existence of code rings for varying-symbol codes and codes formed by boundary arrangements

$$A_k^{k-1}$$

Figures 3, 4 and 5 show examples of code rings for the most frequently used code sets.

The reading of the elements in the code rings may be reversed and the cyclical substitution of its symbols may be transposed. The basic rule of the code ring—that of containing each code of the set only once—is maintained. What is changed is only the order of the codes contained in the set.

For the transmission of a code, certain sectors of the code ring must be reproduced. For this purpose, one can use, for instance, a circular magnetophone band or a drum with a registered closed sequence of signals. The sequence of the signals must correspond to the required symbol arrangement in the code ring used.

The coding device must provide for an accurate selection of the code ring section containing the required code. This can be accomplished with a circular switching system. Here, the representation of each element of the code ring corresponds to the closing circuit or to the sending of a pulse into one of the m possible circuits. The pulse in any of these circuits can be used to trigger the commutating installation which remains excited during n cycles and ensures the reception of the code-ring pulse into the communication channel.

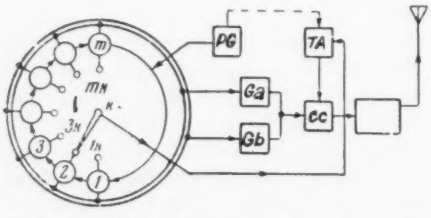


Fig. 6—Block diagram of a telemetric coding device (the distribution principle).

Figure 6 shows a block diagram of such a coding device. Circles 1, 2, . . . m designate the cells of the circular conversion system. At the entrance, pulses flow in continuously from the pulse generator, PG, and cause a successive commutation of circuits 1K, 2K, . . . mk. The continuous flow circuits of the calculating cells are joined into two busbars—in the general case the number of bars is equal to the number of symbols—attached to the generators Ga and Gb. The commutating circuit, CC, controls the imput to the transmitter. Since the commutating circuit, CC, is synchronized by the position of the code key, K, accurate code selection is obtained.

A method of double pulses is useful in some applications. Here the first pulse switches in the commutating device and the second switches it out. The distance between the two pulses is given by the angle of displacement of the brushes on the code arrangement key, and corresponds to the number of the code digits.

Double pulses can also be obtained in one single circuit if the exit circuits of the reading system are connected

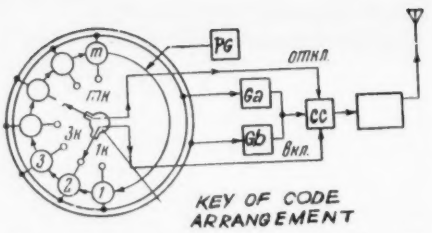


Fig. 7—The double pulse distribution principle.

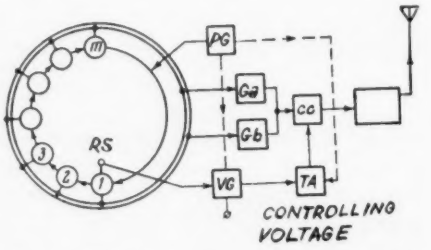


Fig. 8—Block diagram of the telemetric coding device (time-pulse principle).

through valves. The time delay between the valves must relate to the spacing of the brushes in Fig. 7, that is the number of digits in the code. This system makes the use of a double switch unnecessary.

In telemetric devices the switching of the code selection circuits can be determined by the measured quantity itself. Figure 8 illustrates a system which needs no circuit commutation. This is especially advantageous in reading systems. The pulse from one of the code cells of the reading system, RS, is transmitted to the control voltage generator VG which is synchronized by PG, the pulse generator. Depending on the amplitude of voltage applied to VG, the triggering arrangement, TA, is energized for a given section of the code ring. TA, being synchronized by PG, is aware of the start and finish of the code. The system, which is called the time-pulse method, requires accurate coordination of time in selection of the code cell. The matching signals between the triggering circuits and the code-ring pulse must be such that in matching each code-ring element is represented individually.

In the system delineated by Fig. 9, each element of the ring is given a determined amplitude. Thus, the number of the amplitude gradations is equal to the number of the code-ring elements. At the moment of coincidence of the amplitudes of the function voltage FV and of the coded signal voltage, the amplitude selector produces a pulse triggering the blocks which select the required section of the code ring.

Illustrated above are the basic principles of the code rings in telemetric devices. In remote control, the uninterrupted sending of codes is not required so a somewhat different method of

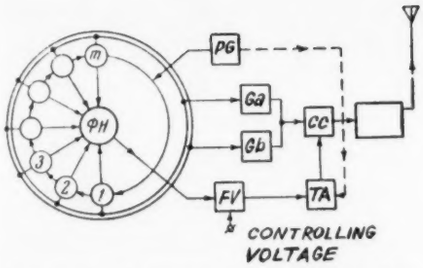


Fig. 9—Block diagram of telemetric coding device (based on principle of functional voltage).

coding is desirable. One of the cells of the registering system is excited just before the sending of the code, then, a series of pulses corresponding to the number of code digits is transmitted to the recording system. During the operation of the recorder, the excitation of the selected cells is transmitted in turn to the contingent cells. The selection of the code is determined by the number of cells of the recorder that had been excited earlier.

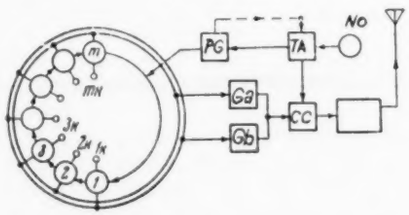
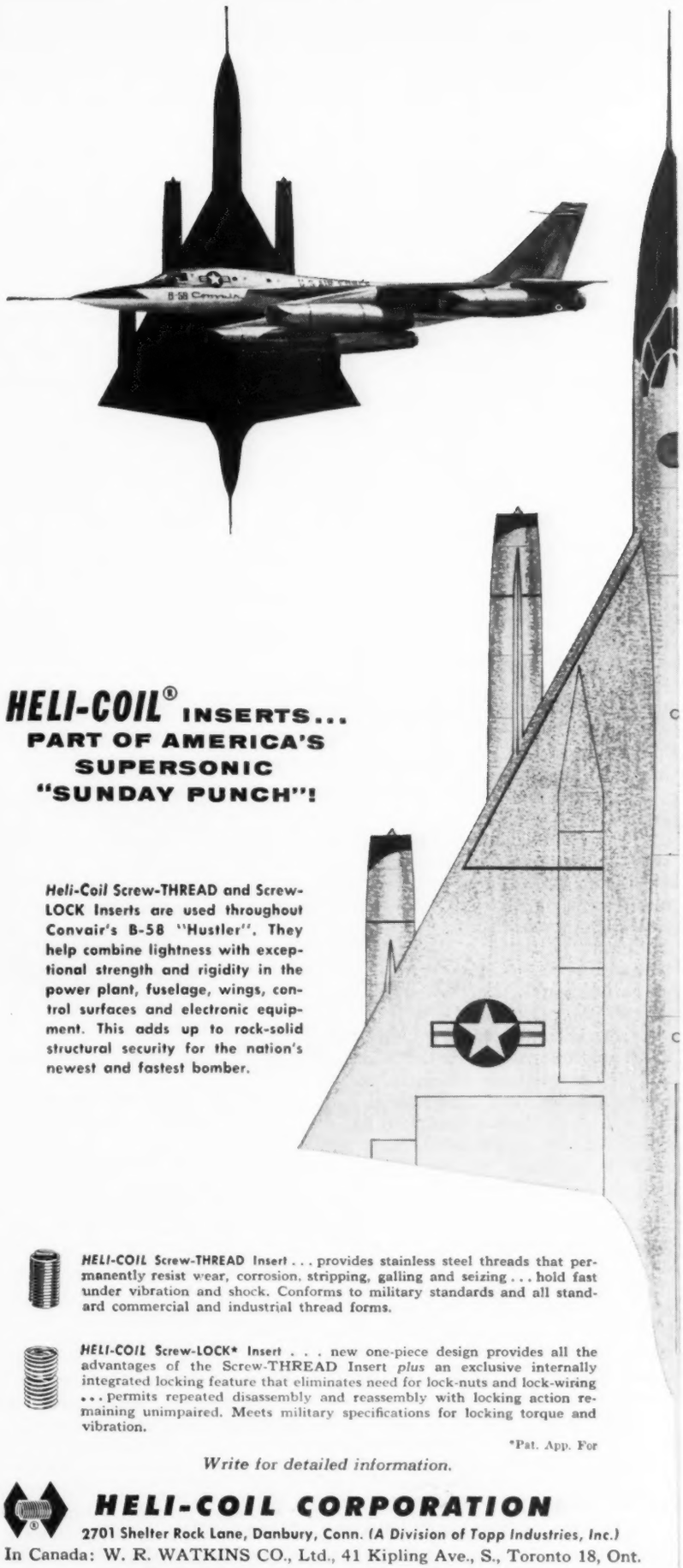


Fig. 10—Block diagram of a ring coding telemetric device for remote control.

Figure 10 shows a block diagram of such a coding device. The advance excitation of the registering cells is done via the keys 1k, 2k, . . . mk. The pulse generator, PG, is triggered by TA which, in turn, is excited by NO. The required number of pulses is obtained by the calibration of the duration of the triggering pulse. The operation can further gain in precision by synchronizing TA by PG. Simultaneously with the triggering of PG, the triggering device switches in CC, which connects the selected section of the code ring to the transmitter.

The code ring principle for telemetering and remote control aims at combining the simplicity of the distribution system with the elimination of interferences for the coding systems. Furthermore, the dramatically simplified ciphering systems and coding devices can be easily constructed on contactless elements.

The original article appeared in the Russian publication Avtomatica i Telemekhanica (*Automation and Remote Control*), August 1957, Vol. 18, No. 8, pg. 756-763.



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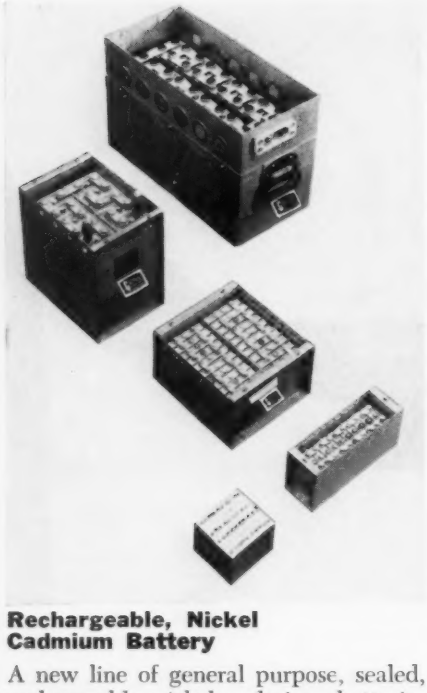

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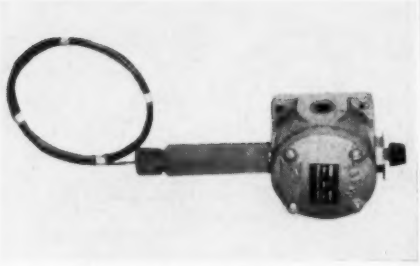
Explosion-Proof Remote Temperature Control

An explosion-proof remote bulb temperature control designed for use in hazardous locations where explosive vapors or gases are present is composed of two integral assemblies: remote bulb thermal device and control head with connecting capillary tube of varying lengths. The remote bulb is exposed to the source to be controlled. The connecting capillary leaves the control head, with its attached bellows, free to be placed away from the source that is to be controlled. The thermal system consists of a bulb, capillary tube and bellows filled with a temperature sensitive liquid. The heating or cooling of this liquid expands or contracts the bellows which operates a snap acting switch at a preset temperature. Head compensation, standardly provided, is effective from −65°F to +160°F.

Temperature settings are made with an external adjustment knob and calibrated dial. Models are available with adjustable range spans of 100°F or 200°F between the limits of −150°F and 650°F with on-off differentials of approximately 1°F and 2°F.



Its new cast iron enclosure makes the E95 more compact and less expensive than previous models. Approximate weight −5½ lbs. This enclosure also permits the use of this control in Class I, Group C and D locations as defined by the National Electrical Code.

Switches are available in any one of three standard types: normally open, normally closed, or double throw with no neutral position, and are rated for 15 amps at 115 or 230 volts A.C. All switches are single pole and suitable for 180°F ambient temperatures. *United Electric Controls Co., Watertown, Mass.*

Circle No. 198 on Inquiry Card.

Two Speed Servo Motor Gearhead

A unique two-speed precision servo motor gearhead represents the first known multi-speed, single package gearhead ever produced, according to the producer.

Named X-544, the unit changes ratios internally when DC voltage is applied to, or removed from, an actuating solenoid. As originally designed, the X-544 is energized at 27 VDC and is de-energized at 4 VDC or lower; but these are only typical values. Ratios in the Size 14 unit pictured are on the order of 1800:1 de-energized and 36,000:1 energized. Similar two speed units are available in all ratios or combinations of ratios required. Units are furnished with housings to mount to servo motors. Designed for integration with Sizes 11, 14 or 18 motors, the X-544 requires 0.008 inch-ounces of starting torque and will operate 12 inch-ounces of load torque. Operating at the higher ratio, the assembly features a backlash maximum of 1° with a 5 inch-ounce reversing load and it introduces not more than 5 minutes of position change when it shifts speed. It operates in an ambient temperature range from −40°C to 125°C.

Primary applications are in positioning computing mechanisms which require fast approaches but slower zeroing or synchronizing action. Advantages include small size and light weight, low heat dissipation, low power consumption and over-all reduction in parts compared to older methods of accomplishing two-speed servo control, with a consequent increase in reliability. *Bowmar Instrument Corp., Fort Wayne, Ind.*

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A new drafting pencil, the Mars Technico push-button lead holder, has a knurled finger-grip that eliminates possibility of the pencil slipping in the hand. The lead holders are balanced, light in weight, have a noiseless smooth-working, low-friction clutch mechanism to hold leads securely. The pencil is available with degree-markings (both fixed and adjustable) for time-saving, positive identification of leads.

In keeping with today's tendency toward increased use of lead holders, the Mars Non-Print now comes in lead form for use in holders. Mars Non-Print "drops out" notes and sketches when drawings are reproduced by processes such as blueprint, brownprint, or Ozalid. Therefore, Non-Print leads allow for complete freedom to sketch and make notes on drawings, without cleaning them up for reproduction. The company marketing this new pencil is also sponsoring a contest for designers. Circle the inquiry number for information on both items.

J. S. Staedtler, Inc., Hackensack, N. J.

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New Electrokinetic Accelerometer

A self-generating, dynamic accelerometer, capable of handling accelerations to 1000 g's has been designed for missile and aircraft applications where high-frequency transients or step-function inputs are expected. The new Accelerometer operates over a frequency range of 3 cps to 60 kc, has a flat response ±6 percent between 5 cps and 40 kc. The acceleration range is from 0.01 g to 1000 g's. Acceleration of 5000 g's will not damage the unit. A 200-g steady-state acceleration will not affect specifications. Transverse response is 5 percent or less.

Outstanding performance characteristics of the unit are made possible by the electrokinetic principle—forcing a polar liquid through a porous substance to create an electric potential across the substance. Being an electrokinetic device, this accelerometer is free from any natural resonances and is therefore aperiodic in nature. This means it will not ring (no natural frequency can be excited), will not "remember" shocks, and will not be damaged by very high-frequency, high-g inputs.

The unit is practically an indestructible transducer. There are no linkages, and the sensing element is completely enclosed in stainless steel. Both flange and stud mounting types are available. They feature a quick-disconnect locking connector and are furnished with 18 inches of twin-conductor, shielded, low-capacitance cable. *Consolidated Electrodynamics Corp., Pasadena, Calif.*

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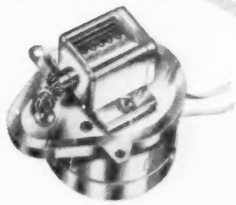

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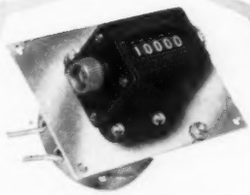

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INPUT VOLTAGE, MIN.:
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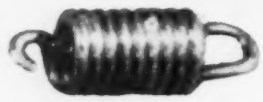

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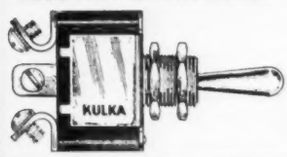

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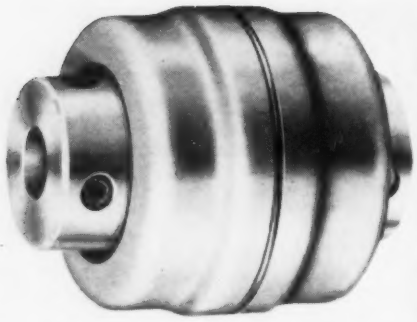

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STAFF COLUMNIST

MARTIN E. KAGAN
Martin E. Kagan is Vice President of Yardney Electric Co.

The Race for What?

Having just returned from an extended trip through Western Europe, my first impulse is to write an account of the latest developments in the various countries which I visited, possibly to give a few specific examples of the work presently done in Europe, cite some of the advances and laggings of our European counterparts, and for rounding out the picture, to compare the role of the engineer over there with that of the engineer here.

This last thought has, however, convinced me the report at this time should be non-technical. Goodness knows, every non-technical magazine and paper in the country has "expertly" analyzed the technical situation we find ourselves in, and has scrupulously drawn up a parts list of the American engineer and scientist. Every item on this list has been thoroughly compared with its European counterpart, particularly the one farthest East. And if we are to believe these surveys, we indeed come off second best in the race.

But, like the artist who every so often has to step back to evaluate his work and see it in full, it takes a trip outside the States to step back and ask yourself the questions: In which race do we show up as the second best? In the race for what? Ask any European engineer and he will tell you: In the race for the mind of man.

Surely we do not believe that the immense technological strength of a nation can be dwarfed overnight by the technological achievement of another nation. Have our tremendous production capabilities been diminished? Have our laboratories been paralyzed? Has our research, which has previously brought forth the very miracles modern man lives by, ceased? Perhaps from a military point of view an illusion was exploded, but what sane man believes that in any future war there will be a winner?

Then, what besides our pride has been hurt so badly? Why the sudden clamor for a new kind of regimented and channeled education? And what in the world or out of it are we trying to achieve? Through the centuries man has had one genuinely human quest: To achieve peace for himself and his children. Peacefully, he could reach the highest plateaus in every field of endeavor or art. At war, to quote the ancient poet, the muses were silent. Yet every logical thought to the contrary, man has always been at war.

Looking into history one sadly comes to the conclusion that war has inevitably been the prime force and drive in forging ahead on newer scientific and technological developments. But one cannot escape the conclusion that this was so only because culturally man has always lagged his technology and, consequently, has never been able to become its master. And now once again we are faced with a huge technological advance, but this time to the point where the cycle may not repeat itself.

Much has been written in the lay press about catching up in the field of science and engineering. Perhaps, for the sake of self preservation, it is up to the engineer-scientist to point out where the real catching up is to be done. For the simple truth one learns everywhere these days is that if there are new boundaries to be broken they are not celestial, and if there is to be a new approach in education it is not to grind out more and better engineers, but rather to broaden our vision so that we may find our way to the hearts and minds of men everywhere.

Nowadays, we have many spokesmen. Almost everyone speaks about us or for us. This intolerable myth of highly developed brains without a mind of its own should not be allowed to be perpetuated. And possibly then we will be able to use the fruit of the brain for the welfare of the mind.

It would be interesting to have some comments.

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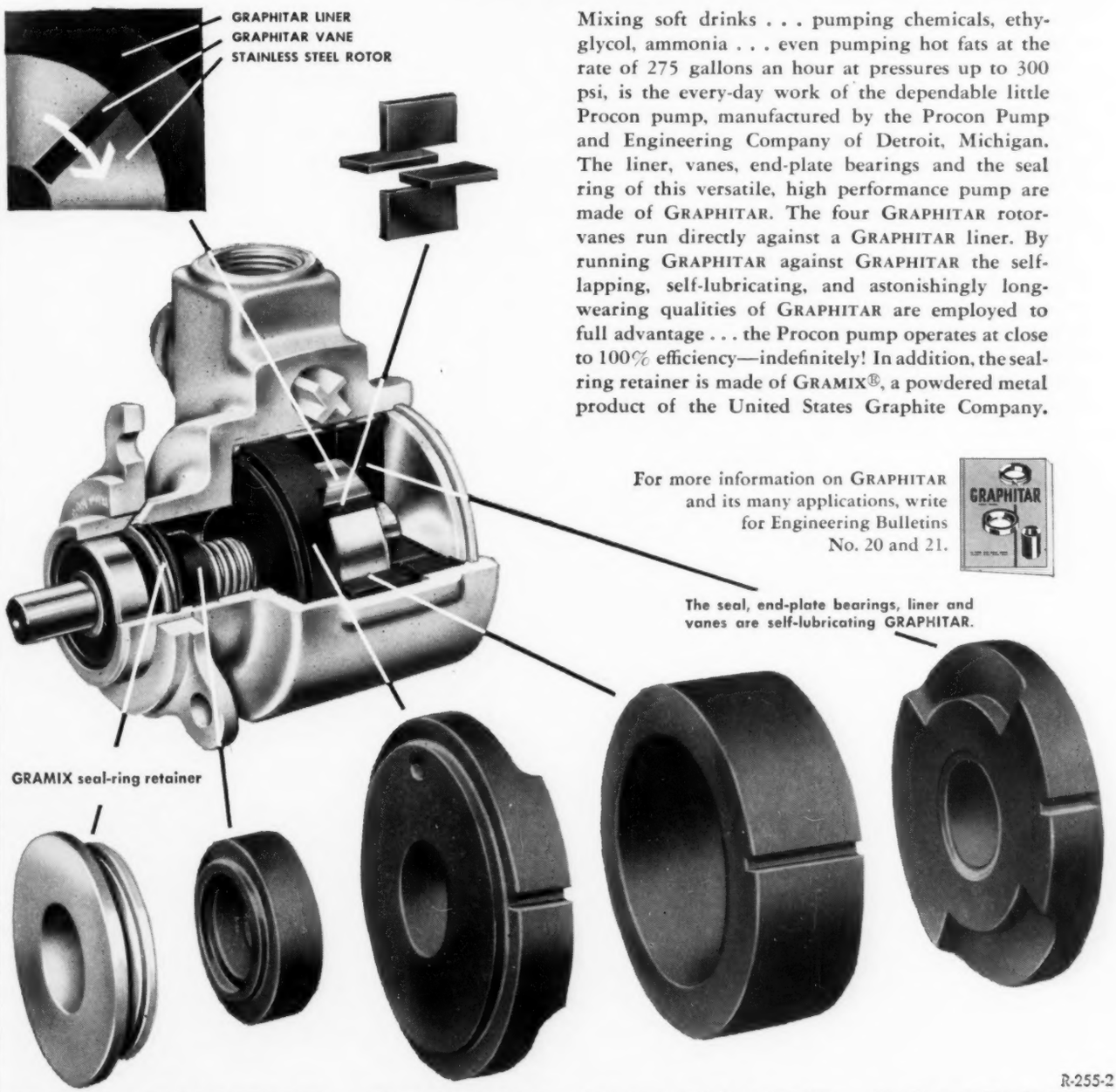
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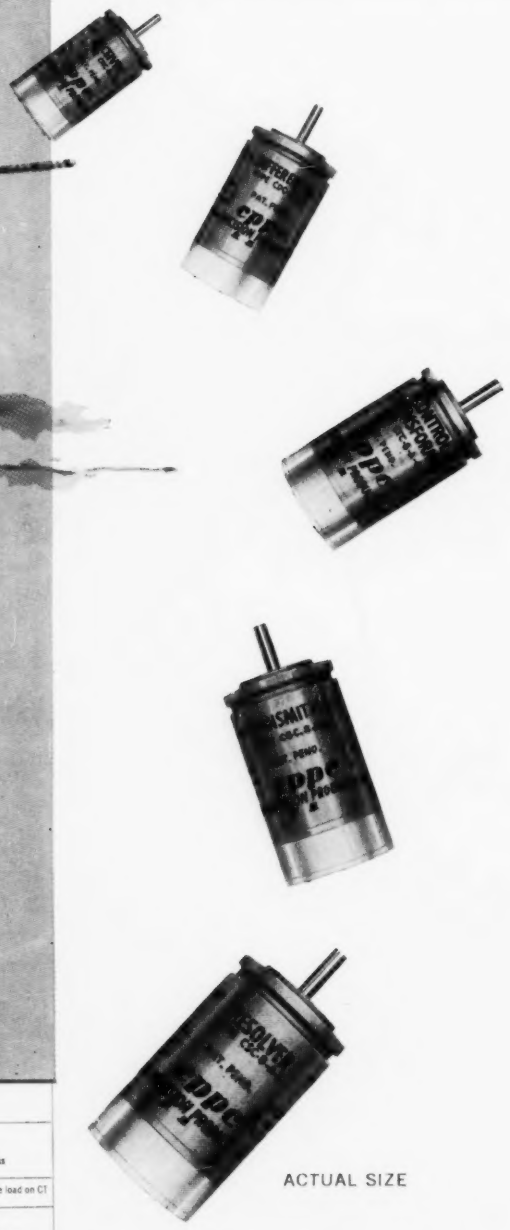

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